Theses and Dissertations   1. Thesis and Dissertation Collection, all items

2010-06

A dynamic model for political stakeholders : forecasting the actions and relationships of Lebanese Hizbullah with Markov decision processes

Burciaga, Aaron D.

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/5296

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

A DYNAMIC MODEL FOR POLITICAL STAKEHOLDERS: FORECASTING THE ACTIONS AND RELATIONSHIPS OF LEBANESE HIZBULLAH WITH MARKOV DECISION PROCESSES

by

Aaron D. Burciaga

June 2010

Thesis Advisors: Moshe Kress
                                 Roberto Szechtman
Second Reader: Michael Atkinson

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE		*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE June 2010	3. REPORT TYPE AND DATES COVERED Master's Thesis
4. TITLE AND SUBTITLE A Dynamic Model for Political Stakeholders: Forecasting the Actions and Relationships of Lebanese Hizbullah With Markov Decision Processes		**5. FUNDING NUMBERS**
6. AUTHOR(S) Aaron D. Burciaga		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) Unified Combatant Command		**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol Number _____

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	12b. DISTRIBUTION CODE A

13. ABSTRACT (maximum 200 words)
This thesis develops a decision theoretic model rooted in Markov decision process theory to provide military and diplomacy decision makers with insights regarding the interests and potential strategies of Lebanese Hizbullah. State trees are used to capture the interests and actions of Lebanese Hizbullah and other relevant countries, political organizations or group. These state trees are used to design an influence diagram that maps the interdependencies of all interests, actions and players. A Visual Basic for Applications tool was developed for the user to generate the sets of data necessary to populate and solve the model's influence diagram. The actions and interests of Lebanese Hizbullah, over time, in the influence diagram constitute a dynamic Bayesian network. At each stage of this dynamic process, Lebanese Hizbullah is characterized by a state and a set of feasible actions that, depending on the actions taken, determine the transition into a new state of the system. This dynamic dependency-bearing model identifies the most important interests, priorities, and capabilities of Lebanese Hizbullah. The resulting assessment of Lebanese Hizbullah's influence, investment, capabilities, and actions reveal key cause-and-effect relations. The utility of such insights may enable decision makers to determine material variables and best courses of action to enhance their strategic decision-making capabilities.

14. SUBJECT TERMS Lebanese Hizbullah; Lebanese Diaspora; Lebanon; Markov Decision Process; Dynamic Bayesian Network; Hidden Markov Models; Decision Analysis; Decision Theory; Decision Tree; State Tree; Influence Diagram; GeNIe; Stakeholder; State Space; Rational Actor; Action; Interest; Distribution; Forecast	**15. NUMBER OF PAGES** 95
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

THIS PAGE INTENTIONALLY LEFT BLANK

**A DYNAMIC MODEL FOR POLITICAL STAKEHOLDERS:
FORECASTING THE ACTIONS AND RELATIONSHIPS OF LEBANESE
HIZBULLAH WITH MARKOV DECISION PROCESSES**

Aaron D. Burciaga
Captain, United States Marine Corps
B.S., United States Naval Academy, 2003

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

**NAVAL POSTGRADUATE SCHOOL
June 2010**

Author: Aaron D. Burciaga

Approved by: Moshe Kress and Roberto Szechtman
                 Thesis Co-Advisors

                 Michael Atkinson
                 Second Reader

                 Robert Dell
                 Chairman, Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

This thesis develops a decision theoretic model rooted in Markov decision process theory to provide military and diplomacy decision makers with insights regarding the interests and potential strategies of Lebanese Hizbullah. State trees are used to capture the interests and actions of Lebanese Hizbullah and other relevant countries, political organizations or group. These state trees are used to design an influence diagram that maps the interdependencies of all interests, actions and players. A Visual Basic for Applications tool was developed for the user to generate the sets of data necessary to populate and solve the model's influence diagram. The actions and interests of Lebanese Hizbullah, over time, in the influence diagram constitute a dynamic Bayesian network. At each stage of this dynamic process, Lebanese Hizbullah is characterized by a state and a set of feasible actions that, depending on the actions taken, determine the transition into a new state of the system. This dynamic dependency-bearing model identifies the most important interests, priorities, and capabilities of Lebanese Hizbullah. The resulting assessment of Lebanese Hizbullah's influence, investment, capabilities, and actions reveal key cause-and-effect relations. The utility of such insights may enable decision makers to determine material variables and best courses of action to enhance their strategic decision-making capabilities.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

All figures are best viewed in color.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

All tables are best viewed in color.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

Diasp	Lebanese Diaspora
DBN	Dynamic Bayesian Network
HMM	Hidden Markov Model
ID	Influence Diagram
IR	Iran
IS	Israel
LB	Lebanon
LB Pop Spt	Lebanese Popular Support
LH	Lebanese Hizbullah
MDP	Markov Decision Process
Mil	Military
NPS	Naval Postgraduate School
SME	Subject Matter Expert
Svc	Service
SY	Syria
UCC	Unified Combatant Command
UN	United Nations
U.S.	United States
VBA	Visual Basic for Applications

THIS PAGE INTENTIONALLY LEFT BLANK

GLOSSARY OF TERMS

Actions: Applications of a stakeholder's resources that (may) influence the state of one or more stakeholders. The set of feasible actions may depend on the state of the system.

Base Case Scenario: A reasonable approximation of values associated with a model's interests and distributions. The Base Case Scenario is not intended to be a perfect prediction of the future, but rather a point of reference by which subsequent models can be compared and even derived for the purposes of both general and sensitivity analysis.

Bayesian Network: A probabilistic model that represents a set of random variables and their conditional independencies via a directed acyclic graph.

Chance: A variable whose outcome is uncertain. The decision maker cannot control it directly.

Controlling Lebanon: The degree to which LH possesses ideological, social, or political control of Lebanese affairs.

Decision: A variable that a stakeholder, as the decision maker, has the power to control.

Defending Lebanon: The degree to which LH is perceived as having the capability and intent to apply military and violent actions toward defending interests of the Lebanese population against threats, especially those originating from Israel.

Diplomacy/Economic/Financial Actions: Negotiations between two stakeholders that frame a range for future economic or financial actions.

Dynamic Bayesian Network (DBN): A Bayesian network that represents a time-series sequence of variables (see Bayesian Network and Hidden Markov Model).

Engage Syria: Form diplomatic, political, or economic relationships with Syria.

Engages Economically: Negotiations leading to the development of economic programs or aid to realize internal or external foreign policy objectives.

Exogenous Support: Stakeholders that influence a system indirectly through their support or influence on a primary stakeholder. Exogenous support is modeled as chance nodes to simplify the model and avoid type III error.

Forecast (Success/Failure): An estimate, based on historical data and experience, of the result of a future event.

Functionalism: The anthropological thought and application of game theory that holds that customs, institutions or behavior patterns in a society can be interpreted as functional responses to problems which the society faces.

GeNIe: GeNIe is a development environment for building graphical decision-theoretic models. It has been developed at the Decision Systems Laboratory, University of Pittsburgh. It is freeware that had been made available to the community to promote decision-theoretic methods in decision support systems. It has been used in both academic and commercial applications. Its name originates from the name Graphical Network Interface, the original name given to a much simpler interface to SMILE—a larger library of functions for graphical probabilistic and decision-theoretic models. GeNIe is an outer shell to SMILE. GeNIe is implemented in Visual C++ and draws heavily on the MFC (Microsoft Foundation Classes). Models of any size and complexity can be built, limited only by the capacity of the operating memory of the computer on which it operated.

Hidden Markov Model (HMM): A statistical model in which the system being modeled is assumed to be a Markov process with unobserved state. An HMM can be considered as the simplest dynamic Bayesian network. In a regular Markov model, the state is directly visible to the observer, and therefore the state transition probabilities are the only parameters. In a hidden Markov model, the state is not directly visible, but output dependent on the state is visible. Each state has a probability distribution over the possible output tokens. Therefore, the sequence of tokens generated by a HMM gives some information about the sequence of states. The adjective 'hidden' refers to the state sequence through which the model passes, not to the parameters of the model; even if the model parameters are known exactly, the model is still 'hidden'.

Information/Intelligence Actions: Use of propaganda, doctrine and intelligence gathering capabilities.

Interests: Issues, goals and objectives that a stakeholder cares about. Interests are discretized into 2-3 levels of importance. The interests are shown as Diamonds in the influence diagrams.

Markov Decision Process (MDP): A time-varying stochastic process, which has a discrete (finite or countable) state-space. A decision maker may choose any action available which then randomly moves the system to a new state where the decision maker may choose any action available in the new state or receive a corresponding reward.

Military Strike: Pursue military option aimed at reducing threat capability. Military strike options not specified, but could include Iran, Lebanese Hezbollah, or militant Palestinian groups (such as Hamas).

Military/Law Enforcement: Demonstration or application of violence, either internal or external, to achieve the actor's interests.

Payoff: Associated to each possible outcome of the model is a collection of numerical payoffs, one to each stakeholder. These payoffs represent the value of the outcome to the different stakeholders (Straffin, 2006).

Political/Diplomatic Focus: Exercise influence primarily through emphasis of political participation in Lebanon's government and de-emphasis on the role of LH's "resistance" militia.

Protect/Svc Shia: The degree to which LH is perceived as having the capability and intent to provide for the welfare of the Lebanese population. This capability is derived from its ability to provide social services such as hospitals, schools, etc. toward improving the status and livelihood of the Shia, in particular, and other Lebanese citizens, in general.

Rational Choice Theory: A stakeholder reasons before taking any action to meet specific interests while maximizing payoff. Assuming rationality means we expect stakeholders to choose actions based on probabilistic forecasts that analyze their payoff as the system transitions to its next state. Rational stakeholders seek to strategically maximize their expected utility.

Regional Influence: The degree to which an actor's (in this case Syria) ability to shape regional economic, military, or diplomatic parameters to suit its interests improves (or degrades).

Regional Stability: Increasing or decreasing the degree to which the region is absent of chaos and disorder, as these conditions are viewed as contrary to Israel's interests.

Resisting Israel: The degree to which LH is perceived as bearing the "mantle of resistance" against its sworn enemy Israel, using any means at its disposal (from propaganda to terrorism) to actively oppose any Israeli action that might be contrary to the interests of Lebanese Shia, other Lebanese citizens, or Arabs in general.

Reward: A quantitative criterion, which in the context of this thesis, stakeholders are trying to maximize.

Salience: The degree to which a stakeholder will apply finite resources to achieve its interests—it is how much a stakeholder cares about the outcome of the political/military situation.

Shocks: Events that have a significant impact on the outcome of the situation. Shocks may be triggered by stakeholders' actions or by external events (e.g., nature, non stakeholder entities, etc).

Stakeholders: Countries, political organizations, or groups that play a key role in the evolution and outcome of a political/military situation.

State of the System: The union of the current states of the stakeholders.

State Space of the System: The set of all possible states of the system.

State Space: The set of all possible states of a stakeholder.

State: An array of interests along with their levels of importance. Each unique interest/level combination represents a unique state of an actor. For example: In the case of Israel, improving security AND increasing regional stability would represent its ideal state (i.e. utility value=100) while deteriorating security and decreasing regional stability would represent the least favored state (i.e. utility value = 0).

State Tree: A vertical depiction of a stakeholder's set interests and the associated utility values of all feasible combinations of interests. Sometimes called expected utility models.

Subject Matter Expert (SME): A person who is an expert in a particular area. In this thesis, the SMEs were anthropologists, historians, economists, mathematicians, military experts and diplomats specializing in Middle Eastern affairs from the UCC.

Success: Achieving a desirable result commensurate with the resources expended.

System: A model of the organizational structure in a political situation.

t=t+1: 't' indicates the current time period. 't+1' indicates the next time period. An arrow with this expression indicates a time dependency relationship. The condition of the "head node" at time t+1 depends on the condition of the "tail node" at time t.

Tornado Diagram: A style of plot that shows the relative importance of variables particularly useful in sensitivity analysis. The 'sensitive variable' is modeled as uncertain or varying while all other variables remain constant according to their assigned base case value.

Type III Error: Typically known as asking the wrong question and using the wrong null hypothesis. We extend the definition of Type III error to mean the error of having solved the wrong problem... when one should have solved the right problem" or "the error... [of] choosing the wrong problem representation... when one should have... chosen the right problem representation" (Mitroff and Silvers, 2009).

Unified Combatant Command: A United States joint military command that is composed of forces from two or more services that are organized with either a geographical or functional basis.

Value: A relative measure of the importance of a certain outcome to a stakeholder; it is a function of the interests achieved in a particular situation.

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Models of political stakeholders that capture their influence, investment, capabilities and actions can help understand key relationships in complex situations such as war, terrorism, coercion, and political power shifts. These insights enable governments, like the U.S., to shape how friendly and adversarial behaviors evolve over time by identifying key variables and best courses of action to enhance strategic decision-making capabilities.

In this thesis, we develop a decision theoretic model to answer a question posed by a Unified Combatant Command: "Will Lebanese Hizbullah decrease its use of internal/external violence to attempt to become a larger part of the political process?" We begin our decision-analysis approach by identifying the set of stakeholders, their interests and feasible actions. The literature reviewed and opinions of subject-matter experts regarding Lebanese Hizbullah provide a design for the model, which contains five interests and eight feasible actions. Lebanese Hizbullah's interests are to: 1) protect and provide services to the Shi'a throughout Lebanon; 2) possess and maintain a militia capability; 3) resist Israel; 4) defend Lebanon; and 5) control Lebanon. Lebanese Hizbullah's actions are to: 1) develop a closer relationship with Iran; 2) increase political maneuvering; 3) increase outreach to the Lebanese Diaspora; 4) expand goods and services beyond the Shi'a in Lebanon; 5) provoke or attack Israel; 6) increase illicit actions; 7) sponsor or conduct a terrorist attack; and 8) increase support to Hamas.

State trees, which are similar to decision trees, are used to capture the order and assigned value of each combination of Lebanese Hizbullah's interests. These hierarchal relationships are then incorporated in the design of an influence diagram. An influence diagram represents the probabilistic and temporal dependencies associated the model components. Influence Diagrams model the stakeholders decision situation and capture actions, state transitions, and

rewards. Future rewards and the successive state of the system are conditionally independent of all previous states and actions (a property of Markovian Decision Processes).

Lebanese Hizbullah is the influence diagram's main stakeholder and sole decision maker. Our subject matter experts identify the model's secondary participants as being the Lebanese Diaspora and the Lebanese populace. The interaction of interests, investment, capabilities, and actions of the stakeholder and secondary participants identify the temporal relationships that provide the basis for the dynamic model's implementation in computer software. The addition of time as an element in our model makes the full implementation of the system a Dynamic Bayesian Network. Each period of time in the model represents one year. The model evaluates Lebanese Hizbullah over a three-year period. A software tool, scripted in VBA and named DMAPS: A Dynamic Model for the Analysis of Political Stakeholders, provides a user-interface to populate the model's parameters and calculates the values necessary to solve the dynamic model.

We examine three scenarios in this thesis. In each scenario, we perform sensitivity analysis by changing the values associated with Lebanese Hizbullah's interests or the distributions associated with its actions. In the first scenario, interests and actions are based on data provided by subject matter experts. The resulting optimal strategy is to "provoke or attack Israel" in year one, "increase illicit activities" in year two, and "seek to develop a closer relationship with Iran" in year three. This remained the optimal strategy for all but one alternative examined in the sensitivity analysis. The sensitivity analysis performed for the first scenario identifies "Lebanese Hizbullah's interest of protecting and providing services to the Shi'a throughout Lebanon" as the most important variable—an interest that the U.S. could influence in order to engineer a more favorable environment in the Middle East.

The second scenario differs from the first scenario by valuing the interests equally. In this case Lebanese Hizbullah's interest in "possessing a militia capability" and "protecting and providing services to the Shi'a in Lebanon" are the most sensitive to variations, i.e., U.S. influence.

In the third scenario, the values of the interests are returned to their subject matter expert values in scenario one, however the distributions associated with Lebanese Hizbullah's actions are varied. Under these conditions, the interest of "Lebanese Hizbullah protecting and providing services to the Shi'a in Lebanon" remains the most important interest in the model.

The reliability of the results and conclusions in this thesis depend upon the quality of the user/subject matter expert data input. Therefore, the U.S., Israel and the West need to invest in fully understanding the interests that drive Lebanese Hizbullah and the potential actions it can take to achieve its objectives. The model presented in this thesis (and extensions of it) can be used to analyze what Lebanese Hizbullah may do in the coming years. The conclusions from this model can also provide insight to policymakers into what can be done to influence Lebanese Hizbullah (and even other stakeholders in new scenarios) to yield more favorable and peaceful conditions in the Middle East.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

For all my fellow service men and women.

With the amazing support and influence of my wife, children, parents, and faith, all things are possible. My life's work is dedicated to them.

Special thanks to Roberto Szechtman, Moshe Kress, Michael Atkinson, and the many subject matter experts who gave so much of their time to guide me in the development of this body of work—their incredible minds, dedicated mentorship, and unbridled efforts to assist me in this thesis will forever be a source of personal inspiration and motivation.

THIS PAGE INTENTIONALLY LEFT BLANK

I.   INTRODUCTION

Note: throughout this thesis, all new terms are introduced in bold and italicized text, referring the reader to the Glossary of Terms for its definition.

A.   OBJECTIVES

The reason that being able to predict those things is important… [is] because if you can predict what people will do, you can engineer what they will do. And if you can engineer what they do you can change the world, you can get a better result.

- Bruce Bueno de Mesquita, 2009

1.   Modeling Political Situations

Models of political stakeholders that capture their interests, priorities, and capabilities can help understand key relationships in complex situations such as war, terrorism, coercion, and political power shifts.

Governments, like the U.S., which possess an interest in trying to shape an outcome, can leverage decision-analysis models to gain insights about best responses involving other ***stakeholders*** and in doing so can then shape the process in which their behaviors evolve over time. A thorough assessment of the influence, investment, capabilities, and actions of each political stakeholder can be used to develop dynamic models that capture the key cause-and-effect relations resulting from actions by stakeholders. The utility of such insights may enable decision makers to determine key variables and best courses of action to enhance their strategic decision-making capabilities.

2.   Application

A decision-analysis approach is useful for understanding and ultimately influencing the outcome of key Middle Eastern issues, such as terrorism and trends of violence. The U.S. and other Western stakeholders, along with

1

traditional Middle Eastern powers, such as Iran and the Kingdom of Saudi Arabia, are vying to shape the their own futures, often leveraging their influence over smaller nations and political entities that could play pivotal roles in the transition of the **state space** toward, or away from, their respective interests. One such pivotal stakeholder that could significantly impact the future stability of the Middle East is Lebanese Hizbullah (LH). The balance of power in the Middle East could tip in or out of the favor of the West based on how the region evolves in relation to LH's political situation.

This thesis develops decision theoretic models rooted in **Markov decision process** (MDP) theory to provide analysis to a Unified Combatant Command (UCC) for the following question:

> Will Lebanese Hizbullah decrease its use of internal/external violence to attempt to become a larger part of the political process?

A Visual Basic for Applications (VBA) interface with **GeNle** is used to depict and analyze the **system's** resident stakeholders, **interests** and **actions** in a **dynamic Bayesian network** (DBN). At each stage of this dynamic process, each stakeholder is characterized by a state and a set of feasible actions that, depending on the actions taken by all stakeholders, determine the transition into a new **state of the system**. A stakeholder's transition to a next state may not be deterministic, but rather subject to random variations and possible shocks (unforeseen events that may have a significant impact on the evolution of the system), which we will refer to as 'shocks to the system'.

3.   Methodology

We first identify the set of stakeholders, the key concerns of each stakeholder, and the feasible actions they can take based on the opinions of subject matter experts and open source historical data. **State trees** are used to capture the order and assigned value of each combination of interests. These hierarchal relationships are then incorporated in the design of influence diagrams. Given the state of the system in each time step, each stakeholder

chooses a feasible action. These actions transition the system to its next state based on distributions that result in each stakeholder attaining some ***reward***. Future rewards and the successive state of the system only depend on the present state of the system, meaning that it is conditionally independent of all previous states and actions (this is the Markovian property). The MDP model provides results for the analysis of the interdependencies resulting from stakeholder actions and interests.

B. SCOPE, LIMITATIONS, AND ASSUMPTIONS

This thesis provides an MDP decision theoretic model to capture the political dynamics and forecast potential strategies relating to the LH question. At each stage of the dynamic process, the primary stakeholder and ***exogenous support*** are characterized by a state and a set of feasible actions that will, at the end of each stage and depending on the actions taken by all stakeholders, determine the transition into a new state of the system. The set of feasible actions and the distribution associated with each action are based on the precepts of 'rational play', which are discussed at length in Chapter II, Section C.1.

Results of this thesis are limited only by constraints on time and the capacity of the operating memory of computer software (GeNIe allows for building models of any size and complexity).

C. OBJECTIVES

This thesis delivers a decision support tool that provides military and diplomacy decision makers with insights regarding the potential strategies that LH might pursue as it seeks to become a larger part of Lebanon's political process. The analysis of LH's interests and potential strategies reveals opportunities, otherwise not identified, for affecting aspects of Lebanese Hizballah that would result in favorable outcomes for the US and its Middle Eastern allies.

D. COURSE OF STUDY

The course of study pursued by the author was to collect, develop, and test data, as shown in Figure 1. The opinions of SMEs from the UCC, were instrumental in not only digesting the information gleaned from the literature reviewed, but also in the construction of the influence diagrams and overall modeling of the LH question.
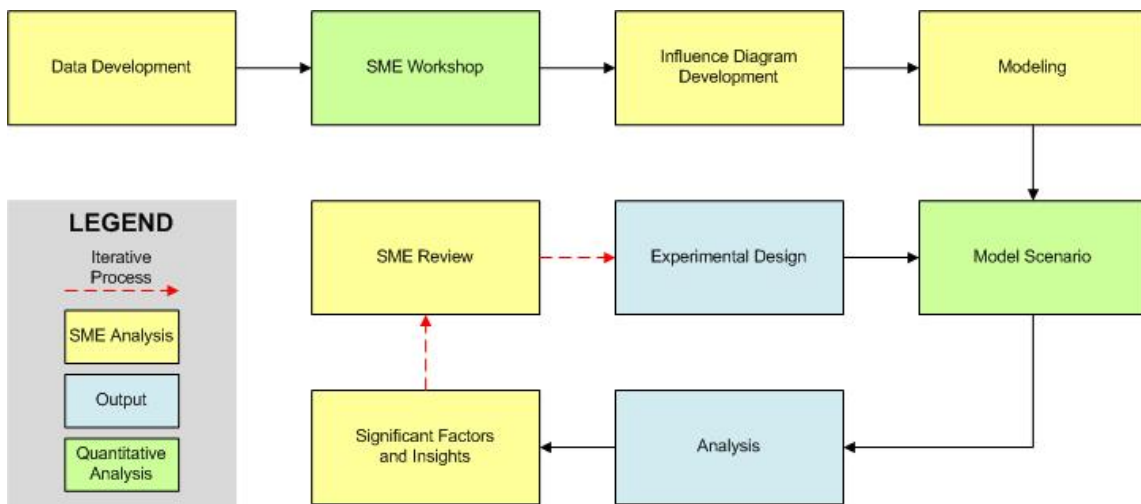
Figure 1.   Course of Study

II.   POLITICAL BACKGROUND AND LITERATURE REVIEW

A.   INTRODUCTION

Lebanese Hizbullah is an important participant of the Middle Eastern political situation that affects peace and prosperity throughout the region. Within Lebanon, and elsewhere in the Middle East, the "followers of Ali" (Shi'a) and the "people of the tradition of Muhammad and the community" (Sunni), struggle for control of the current and future state of the Middle East.

Sunni Islam is the largest branch of Islam, comprising at least 85% of the world's 1.5 billion Muslims. Shi'a Muslims account for only one-tenth of the Muslim population worldwide (Friedman, 2002). As Iran, Syria, Lebanon, Israel, Saudi Arabia and other Arab states vie for economic position and subsequent political survival, the Sunni and Shi'a divide is an important component toward understanding how allies, interests and actions align. One of the pioneers of political forecasting summarizes the situation that this thesis explores as follows (Bueno de Mesquita, 2009):

> *The basis of Palestinian-Israeli conflict resides, at least for many, in economics, not religion. Religion is a politically useful and easy organizing principle that unscrupulous people use to marshal support, but it is not what the fight was or is primarily about. The fight is about land in a locale where, for most, the economy was historically tied to owning property, just as it is in all traditional societies. The economies in the territories… still rely significantly on land, but not nearly as much as they did decades ago…. Agriculture [now] plays a much altered role… [They] aspire to a significant degree to have a modern, service-based economy… These are the conditions that are ripe for a self-enforcing incentive plan.*

This thesis uses four criteria of data to provide analysis of how LH might decrease its use of internal/external violence to attempt to become a larger part of the political process. The first criterion identifies all stakeholders. The second

criterion examines each stakeholder's set of feasible actions. The third criterion identifies stakeholder interests. The fourth criterion looks at how a stakeholder develops its ***forecast***.

The following sections of Chapter II provide the historical and cultural background requisite to the first criterion, which is to identify the model's stakeholders. We also examine methodology and past efforts for developing political forecasting tools. In Chapter III, we address the three remaining criteria and their application to the data and methodology used in this thesis model.

B. HISTORICAL AND CULTURAL BACKGROUND

The history of the Middle East and cultural backgrounds help us identify and understand the entities that will be necessary to structuring our LH model.

1. Stakeholder: Lebanese Hizbullah

The Shi'a political movement that began in Lebanon in the 1970s, known as the Lebanese National Movement or Movement of the Deprived, is carried on today by LH. Sayyid Hasan Nasrallah, then a 22-year old young revolutionary and former Amal representative, gained prominence through his aggressive efforts to safeguard territorial integrity in Southern Lebanon (Qasim, 2005). Following Israel's invasion of Lebanon in 1982, Hizbullah was organized to fight against the Israeli occupation. Having assumed control of what had been a cabal of revolutionaries; Nasrallah led the formation of a coherent resistance organization, which was named Hizbullah, meaning literally the "Party of God" as interpreted and derived from the Qur'an (Qassem, 2005):

> *Your friend can be only Allah, and His messenger and those who believe, who establish worship and pay the poor due, and bow down [in prayer]. And whosoever taketh Allah and His messenger and those who believe for friends [will know that], Lo! The party of Allah, they are victorious.*

6

Such adherence to Islam and its precepts have resulted in LH's emergence as a revered, supported, and successful resistance movement in Lebanon. Whereas previous Islamic resistance movements like Amal had faltered, LH was able to gain support and credibility by characterizing its actions as terrorist strikes designed to liberate Israeli occupied lands. These very well organized strikes, on a series of Israeli targets that had previously been impenetrable, quickly garnered praise and encouraged the imaginations and hope for what LH could yet achieve. LH had become, and to this day remains, first and foremost, a 'resistance organization'.

Critics of LH's early success accused both the organization and Nasrallah of repeating the mistakes of Amal, that they were premature in assuming victories and fame. Critics scoffed:

> Who authorized Nasrallah to represent all the Lebanese to make decisions for them and to embroil them in something they don't want to be embroiled in? Did Nasrallah appoint himself secretary general of all the Lebanese and the whole Arab world? (Norton, 2007)

Notwithstanding criticism, LH was able to string together a series of strikes in Southern Lebanon whereby in May 2000, Israeli troops withdrew from portions of the areas they occupied. Lebanon had never before been able to perceive itself as being able to put Israel on its heals, and yet now, through LH, it had done just that for the first time in more than 50 years of struggle along its southern border (Qassem, 2005). As a result, it quickly won the praise of both Lebanese nationals and foreign Shi'a Muslims (e.g. Iran) who were sympathetic to its charter.

Though not a state in and of its own right, LH is an extremely influential stakeholder when considering Middle Eastern politics and the Islam's resistance of Israel and the West. LH has grown remarkably since becoming a coherent resistance organization in the mid 1980s; no longer merely a resistance operation, LH has also become a provider of an extensive network of social services and is also a formidable political party within Lebanon. Advocating the

sympathies and support of Shi'a Muslims, LH defines its own self as an Islamic organization, whose objectives are to: 1) provide a comprehensive and complete program for a better life within the tenants of Islam; 2) employ the full capabilities of the Arab world to resist Israeli occupation through militant jihad; and 3) establish order whereby Muslims are united under the supreme leadership of the Jurist-Theologian (Qassem, 2005).

LH has further secured the confidence, cooperation and participation of Shi'a Muslims by dedicating an enormous amount of its resources toward providing social services. The Lebanese government, corrupt and ineffective, is unable to provide these services, which in turn galvanizes LH's base. LH has employed its social services to provide relief in the wake of regional conflict and even natural disaster, relief that has often been characterized by medicinal help, meals, reconstruction grants, and interest organizations such as the Islamic Health Organization and the Institution for the Wounded, which it provides (Qasim, 2005).

LH's desire to increase its political legitimacy and influence in both Lebanon and throughout the region comes with an indelible price—it too is at a crossroads where its commitment to future resistance operations must wane if it is to achieve its broader regional objectives. Disarmament and future compromise may be necessary to maximize their *payoff*—a function of their interests as discussed in the Data and Methodology section.

2.   Exogenous Support

a.   *Lebanese Diaspora*

There are more Lebanese living abroad than in Lebanon. Approximately 15 million of the estimated 19 million Lebanese are spread across the globe with more than 3 million in the U.S., roughly equivalent to the population of Connecticut. The majority of the Diaspora's population is Lebanese Christians, outnumbering Lebanese Shi'a and Sunni Muslims by a 3:1 ratio

(Nasr, 2007). Notwithstanding religious identity, the Lebanese Diaspora are in large part still very allegiant to Lebanon, even echoing Lebanon's Anti-Western sentiment—the global spread and influence of so many Lebanese is problematic for Israel and the West. Language, culture, and identity are important to how members of the Lebanese Diaspora stay connected and interested in the affairs of the region. Moreover, the importance of the Diaspora is likely to grow since their continued interest and investment in Lebanon has been encouraged by legislation that allows all Lebanese living abroad to vote in elections by mail beginning in 2013 (Norton, 2007). Through both the power of purse and vote, the Lebanese Diaspora is a stakeholder capable of influencing regional development.

Members of the Diaspora and their businesses provide, both voluntarily and through obligation, extensive financial support to LH. Money is routed to Lebanon through forms of business and charities run by Lebanese. Business transfers, called "qhums," are required from those whom have received business funding from LH and stipulate that said recipients must give back one-fifth of their increase to LH for the life of their business (Norton, 2007). Volunteer donations are often funneled through charities. In Islam, governments do not meddle in charities and no accounting is required, and as such, LH is able to allocate money as needed or desired–toward hospitals or ammunition.

b. Lebanese Popular Support

There are approximately 1 million foreign workers, 400,000 Palestinian refugees, and 4 million Lebanese living inside Lebanon today. The demographics of the population within Lebanon have been affected by the Diaspora. Although Lebanese Christians outnumber Lebanese Shi'a and Sunni Muslims by a 3:1 ratio worldwide, Lebanon has a Muslim majority due to its Christian population having the lowest birth rate of all sects within Lebanon and the predominately Lebanese Christian emigration (Nasr, 2007).

Shi'a Muslims constitute 35% of the population in Lebanon, approximately 20% are Sunni Muslims, 20% are Maronite Christians, and the remainder is composed of other denominations and religious ethnic groups such as Druze (Nasr, 2007). Political representation is proportional to the population of Lebanon's religious distribution. Religious communities form coalitions through negotiations to identify and elect candidates that favor their shared interests. Such cross-confessional cooperation is by design, and was introduced by the Taif accords in 1989 as Lebanon's first attempt to enable Lebanese coalitions to form and serve Lebanese interests, while expelling Syrian influence. Although the struggle to strengthen auto-governance continues to this day, Lebanon's 2005 Cedar Revolution achieved significant milestones by causing Syrian troops to withdraw from Lebanon, instituting a government largely independent of Syrian interests, and organizing free parliamentary elections.

Home to LH and a Shi'a majority, Lebanon's population and government are key to modeling the interaction and interests of this study's stakeholders. The complex nature of its population, the recent assertions and political agenda of its government, and both the domestic and global consequences of emigration, make Lebanon a primary stakeholder in the determination of most Middle Eastern questions.

c. United States

The beginning of the United States' interest in Middle Eastern affairs, can be traced to the early to mid-1900s when the establishment of the state of Israel and the globalization of crude oil trade changed the region's power and economic structure. In contrast to the British White Paper of 1939, which stipulated an independent Palestine proportionally governed by Palestinian Arabs and Jews, Roosevelt's administration favored a more Jewish friendly plan, one that would open "Palestine to unrestricted Jewish immigration and colonization… to result in the establishment there of a free and democratic Jewish commonwealth" (Qassem, 2005). Truman followed by pressuring the British

government to allow more than 200,000 Jewish immigrants to enter Palestine in 1945-1946, then recognized the "State of Israel" eleven minutes after the announcement of the UN declaration ending British mandate in Palestine. The U.S. has since been Israel's most important ally by granting free trade in 1985, providing more than $3 billion in annual aid grants, negotiating billions of dollars in loans guarantees through the U.S.-Israel Joint Economic Development Group, and providing a vast amount of military assistance in terms of technology, equipment and training. These enormous investments and trade favors have caused legions of Arabs to suspect an anti-Muslim conspiracy afoot, and that its conspirators must be defeated to preserve and honor Islam.

The U.S. imports 60% of the oil it consumes from other countries. Although most of the world's oil reserves are located in the Middle East, the U.S. currently imports more crude oil from Canada than any other nation (Friedman, 2002). Imports from Saudi Arabia are second, with Iraq also in the top 10 countries. The bulk of proven, remaining oil reserves are located in the Middle East, and with more than 727 billion barrels of oil in reserve, the Middle East will become an increasingly necessary trade partner for the Unites States' economic survival. This reality is known both east and west of the Mediterranean, and stakeholders on both ends of the sea are posturing to ensure their current and future interests are met through the capabilities they develop today on the diplomatic, military and economic front.

d.   Iran

Iran is LH's most important sponsor. In Iran, Sunni Muslims are outnumbered by Shi'a Muslims by a 1:10 ratio. Iranian politics are dominated by Shi'a influence and the heavy imbalance has quelled all but very few Sunni-Shi'a domestic problems. By sharing the primary denomination of Shi'a Islam, Iran's supreme leader is the same Jurist-Theologian under whom LH promotes the unification and order of all Muslims. LH is, by doctrine, ultimately allegiant to the same individual, Ali Hoseyni Khamene'I, Iran's supreme leader. Their orthodox

roots in Islam mean that Iran and LH share the fundamental beliefs that there be: 1) an Islamic order under the absolute jurisdiction of the Jurist-Theologian; 2) an Islamic republican system of government, as typified by Iran and promoted by LH, which best embodies and supports the fundamentals of Islam; and 3) the absolute rejection of superpower hegemony (Nasr, 2007).

Having a sponsor like Iran is critical to LH's influence, strength and aspirations. Iran channels its support for LH by providing it with the financing, weapons, and training needed to continue its operations. Such support buys Iran influence within LH to have it serve both as a companion and proxy in the struggle against Israel and the West. The symbiotic relationship has thus far ensured the survival of LH while extending Iran's reach westward.

C.   METHODOLOGY AND PAST WORK LITERATURE REVIEW

1.   The Nature and Application of Decision Games

In Philip D. Straffin's *Game Theory and Strategy*, every decision in a game is "the logical analysis of situations of conflict and cooperation" (Straffin, 1996). While conflicts in the Middle East, and more specifically the UCC's question certainly involve both elements of stakeholder conflict and cooperation, we will examine how our proposed model measures to Straffin's definition of a game. He defines the basic nature of such games to be (Straffin, 1996):

1. There are at least two players. A player may be an individual, but it may also be a more general entity like a company, a nation, or even a biological species.

2. Each player has a number of possible strategies, courses of action which he or she may choose to follow.

3. The strategies chosen by each player determine the outcome of the game.

4. Associated to each possible outcome of the game is a collection of numerical payoffs, one to each player. These payoffs represent the value of the outcome to the different players.

Rational play is fundamental to understanding how stakeholders reason before taking action. This is called **Rational Choice Theory** (RCT).

Straffin applies the aforementioned principles of game theory to the anthropological thought known as **functionalism**. He writes that functionalism shapes the decisions a player makes as the "customs, institutions or behavior patterns in a society can be interpreted as functional responses to problems which the society faces." Such perspective in the Middle East could provide valuable insight regarding the organization of societies and how they collectively organize and respond in a variety of situations.

2.   The Essence of Decision Making

We will now examine Graham Allison's *Essence of Decision: Explaining the Cuban Missile Crisis* to understand established decision theoretic nomenclature as it applies to political decision making and gain a historical context of how decision theory has been applied to other major international crises. Allison suggests three broad implications in applying decision theory to political decision making: 1) techniques developed to enhance political decision making can be applied broadly beyond foreign affairs; 2) due to the complex nature of human systems and endless amounts of relevant data, simplification is essential; and 3) predictions come with zero guarantee; however, they do always provide important insight, inferences and perspective that might not otherwise be realized (Allison, 1971).

In his review of the Cuban Missile Crisis, Allison first considered three fundamental facts, as they pertained to the Soviet Union: 1) the USSR was equipped with only 20 ICBMs in 1962; 2) the mere 6 nuclear submarines in the Soviet Fleet would have to travel 7,000 miles from the nearest strategic nuclear submarine base to U.S. shores; and 3) the best hope of threatening U.S. homeland was with fleet of 200 long range bombers (Allison, 1999). These facts implied that the Soviet Union was limited to practically a binary nuclear option: turn from the U.S. blockade and avoid nuclear confrontation, else, ignore the

blockade and pursue the nuclear option. President Kennedy himself realized the razor's edge on which the soviets stood. He told congressional leaders on October 22 that, if the Soviet ships did not stop, the U.S. would be forced to fire the first shot, inviting retaliation and would lead to "war in the next 24 hours" (Allison, 1999).

The former Soviet Union is a good lens through which Allison investigates how the interests of rational stakeholders interact with decisions and state space. The following questions were cultivated though the analysis of the Cuban Missile Crisis, but are applicable and relevant to any situation we could heretofore consider (Allison, 1999):

Where do organizations derive their preferences?

Why does organizational behavior constrain "rationality"?

Why are organizational structures sometimes so particular?

How do organizations relate to their environment?

The final question is especially interesting in how it relates to the issues this thesis considers when modeling Middle Eastern stakeholders. As we consider the political, economic, and historical environment of the Middle East, these following conditions shape how we model: 1) our stakeholders and their **salience**; 2) what factors, such as parochial priorities and goals that shape each stakeholder's interests and the **value** associated with said interests; 3) the weight of each stakeholder on the transition of the system to the next state; and 4) how the interests and decisions of stakeholder's combine to influence their own and other stakeholders decisions and actions.

Allison provides Iraq's 1990 invasion of Kuwait as an example of a rational stakeholder (Iraq) seeking to maximize its payoff through a strategic gamble that was ultimately met and defeated with surprising opposition (Allison, 1999):

Saddam Hussein would never have resorted to such a desperate measure … if Iraq's economic condition had not been so dire… By adding Kuwait's fabulous wealth to the depleted Iraqi treasury,

> *Saddam hoped to slash Iraq's foreign debt and launch the ambitious reconstruction programmes he had promised to his people in the wake of the war with Iran.*

Saddam's miscalculation of how the U.S. and United Nations would respond to his invasion of Kuwait was not due to a lack of rationality, but rather due failing to forecast how Iraq's behavior would interact with the interests and decisions of other stakeholders.

3.   The Logic of Self Interest

The literature reviewed in the previous subsection exemplifies the robust cannon, which historians and mathematicians have penned in thinking about and modeling events that have already happened in the world. To shift from merely projecting the past onto the present, and in order to begin modeling the present to develop and analyze forecasts of the future, we will now review *Predictioneer's Game*, by Bueno de Mesquita. Although his models are proprietary, Bueno de Mesquita suggests that the application of the principles decision theory can help us look at political decision making in a much more rigorous and scientific way (Bueno de Mesquita, 2009). As we endeavor to do so, we must seek to thoroughly understand all criteria, interactions, and causality in the models we seek to develop.

Bueno de Mesquita postulates that politics are predictable. He claims that he has applied decision theory to very basic information that meets the assumptions of RCT, to produce forecasts with a purported 90% accuracy rate. He further writes that "the key to good prediction is getting the logic right, or 'righter' than any way that is achieved by other means of prediction." Bueno de Mesquita suggests that we don't need very much to predict well, in fact, we need to only know the following: 1) who has a stake in trying to shape the outcome of a decision (stakeholders); 2) what they want (interests); 3) how focused they are on the problem at hand (utility); and 4) how much clout they bring to bear (Bueno de Mesquita, 2009). These factors are quantifiable in the LH situation studied in

this thesis, and as such, according to Beuno de Mesquita, we can anticipate reasonable forecasts from the models developed to answer the question posed by the UCC.

According to Bueno de Mesquita, there is no history in forecasting or shaping the future. The dead reckoning of each stakeholder, meaning knowing *where* and *how* they are, enables us to reliably forecast how they and the system will transition. In his own words, "how they got there turns out not to be terribly critical in predicting" (Bueno de Mesquita, 2009).

Other ideas discussed by Bueno de Mesquita, which shape how we formulate this thesis model, are as follows:

1) Metaperception. While it is critical to think about what other stakeholders think about their interests, it is just as important to think about what other people think about what you think about your own interests. This is akin to our assumption of perfect knowledge in the model.

2) Language. Ordinary everyday language can be vague and ambiguous. The dynamics and complexity associated with political forecasting necessitate robust explanations and articulate definitions for each attribute and parameter of the model.

3) Design. In accordance with Nash equilibrium, each stakeholder's interaction within the state space must designed such that they do not have any incentive to take an action that is not included in their strategy (set of feasible actions).

4) Sensitivity Analysis. Because "as you know… men are likely to forget in the heat of action where their best interests lie and let their emotions carry them away."

5) Shocks. Thorough analysis should allow for and examine the effects of exogenous shocks that are products of outside, unexamined forces. Such shocks can wreak havoc on a system.

4.   A Systems Analysis Approach

We next review the paper entitled *Probabilistic Modeling of Terrorist Threats: A Systems Analysis Approach to Setting Priorities Among Countermeasures* (Paté-Cornell and Guikema, 2002). Herein the authors propose a game theoretic systems analysis approach to modeling political decision making. They apply their systems approach to the specific question of modeling potential terrorist attacks and U.S. response scenarios.

The authors order information and manipulate data by first ranking the key interests and states, and then by using a convenient visual and analytical decision support tool: decision trees. Their decision trees consolidate and organize the volumes of information needed to identify the model's stakeholders, states, and interests. An important assumption, necessary to the design of any decision-analysis model, is that all stakeholders are in fact rational actors with a set of interests that can be ranked to determine the probability distribution of feasible actions. The resulting decision trees for each stakeholder are then used to develop a representation of the interdependencies among stakeholders in an influence diagram. Such an influence diagram, they suggest, would allow the consequences of different attack and response scenarios to be assessed. The influence diagram shown in Figure 2 is a representation of the overarching model developed to capture terrorist attacks on the U.S. and the U.S.'s subsequent response.
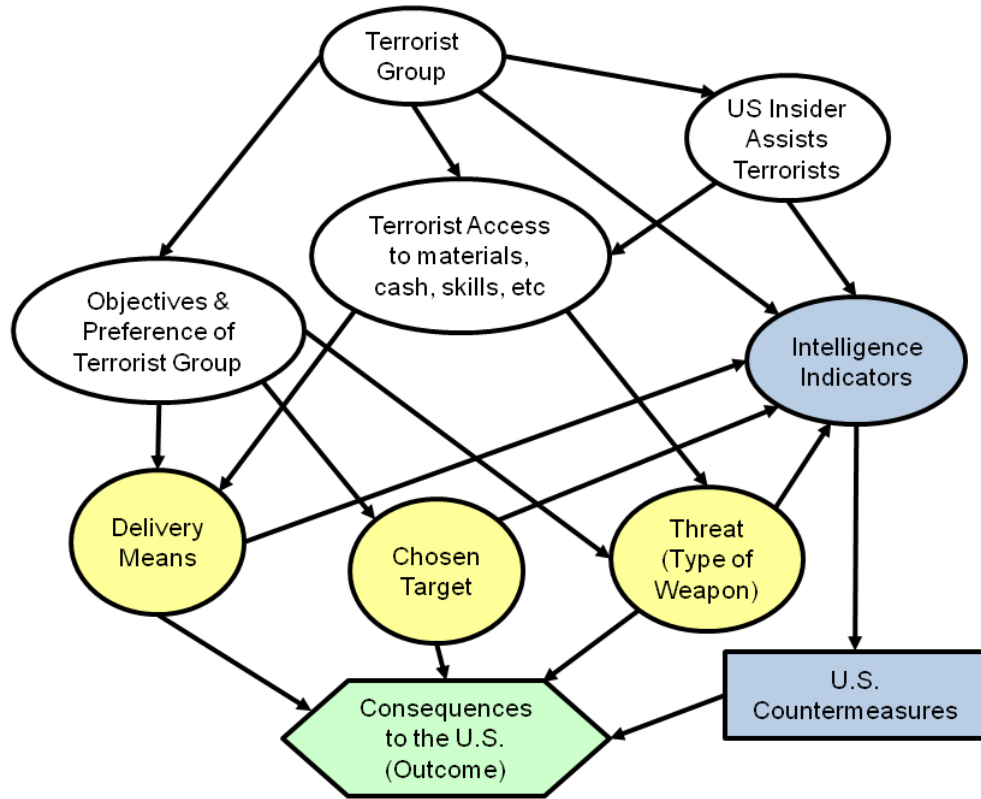
Figure 2.   Influence Diagram (From Paté-Cornell and Guikema, 2002)

The influence diagram in Table 2 captures the benefits of such an overarching systems analysis approach in conveying the known and assumed information as it applies to the system.   Further information regarding methodology and utility of influence diagrams will be discussed later in more detail.

Whereas the aforementioned paper models the system in only one time period, this thesis uses similar techniques to not only identify stakeholders, rank states and interests, and model interdependencies, but it also charts new ground by using dynamic functions to show the results of a multi-time period system. The ability to model the state of a system and decisions taken, followed by subsequent consequences and the system's transition to the next set of decisions, consequences, and so on, adds realism to the forecasts and analysis that these models provide.   The authors identify the need for, and this thesis

endeavors to prove, dynamic modeling as the means to iteratively evolve the stakeholders and state space in order to develop reliable political forecasts.

5. **Systems Engineering**

Systems engineering models, such as those developed by Boeing to aid the UCC in their analysis of LH, are limited in terms of their useful application. These models are designed to represent the system that influences and is influenced by LH. Although these system engineering models paint a very clear picture of system interactions, they are deterministic and involve difference/differential equation models. The model shown in Figure 3 portrays what Boeing describes as the 'characteristics of [LH]' that drive the actions and behaviors of the system. In terms of this thesis, the Boeing model is meant to depict how relationships with other stakeholders drive the interaction of LH interests with state, financial, militia, and religious entities to shape LH's 'capability', 'capacity' and 'legitimacy' in a single time period. This modeling approach fails to incorporate dynamic processes, stakeholder transition, and random variations (shocks) to the system. *Subject matter experts* (SME) workshops quickly identified that the systems engineering models fell well short of providing the sort of analysis and forecasting capability that the UCC ultimately desires.
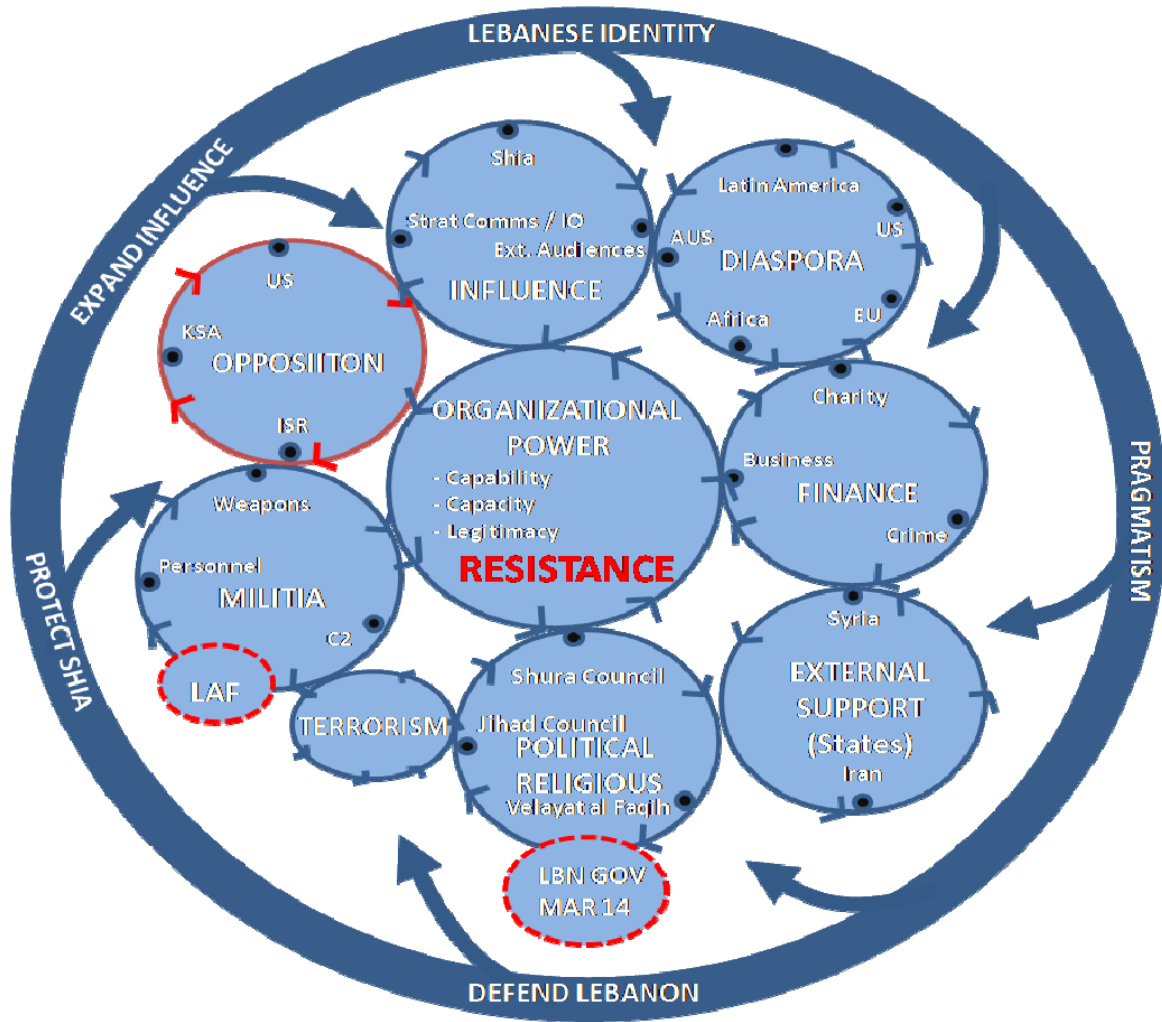
Figure 3.   Boeing's LH Systems Model (From UCC, 2009)

III.   DATA AND METHODOLOGY

A.   DATA

1.   Introduction to Feasible Actions

Feasible actions are manifested by the application of a stakeholder's resources that (may) influence the state of one or more stakeholders. Consequentially, a stakeholder's set of feasible actions may depend on the state of the system. In this thesis, actions are categorized according to Diplomacy, Information, Military, Economic, Finance, Intelligence, and Law Enforcement.

In order to simplify the design of the model, we merge the set of categories from seven to just three: 1) Diplomacy, Economic and Financial actions; 2) Information and Intelligence actions; and finally, 3) Military and Law Enforcement actions. Diplomacy, Economic and Financial actions shape negotiations between two stakeholders, which frame a range for future economic or financial actions. Information and Intelligence is the term used to describe the use of propaganda, doctrine and intelligence gathering capabilities. Military and Law Enforcement actions are any demonstration or application of violence, either internal or external, to achieve a stakeholder's interests.

2.   Lebanese Hizbullah Actions

We have identified eight feasible actions whereby the interests of LH are tenable. The first two fall within the scope of Diplomacy, Economic and Financial Actions. LH would be able to further develop the social services it provides to the Shi'a, strengthen its militia, and expand its influence throughout Lebanon by 1) developing an even closer relationship with Iran; or 2) Increase political maneuvering within Lebanon. Both of these diplomatic options more or less continue trends that have already been manifested. LH could conceivably strengthen its legitimacy as a political party by continuing to pursue actions that prove successful to these ends.

The SMEs helped us to identify how LH could choose to leverage information and intelligence operations to further its interests. Such operations would include 1) increasing the organizations outreach to the Lebanese Diaspora; and 2) expanding goods and social services beyond just the Shi'a populace. While outreach to the Diaspora could yield huge financial dividends, befriending non-Shi'a Muslims, Christians and Lebanese of other denominations could result in LH gaining a majority in Parliament to ultimately attain what has seemed unattainable—political control of Lebanon.

Finally, there are four Military and Law Enforcement actions available to LH. Through their militia, they may choose to 1) provoke or attack Israel; 2) increase illicit actions; 3) sponsor or conduct a terrorist attack; or 4) increase support to Hamas. Our SMEs believe that presently, actions 1 and 3 seem unlikely, while actions 2 and 4 are likely preferred ways of continuing their resistance to Israel and the West, albeit through less formal, or even surrogate, channels.

3. Lebanese Hizbullah Interests

In the context of this thesis, LH's interests have been defined by the author and SMEs as being to: 1) protect and provide services to the Shi'a throughout Lebanon; 2) possess and maintain a militia capability; 3) resist Israel; 4) defend Lebanon; and 5) control Lebanon.

Protecting and providing services to the Shi'a was once an ancillary mission for LH, but it is now its single most important, recognized and supported operation. It has gained legitimacy by providing the basic services that the Lebanese government could not (Norton, 2007). LH's network of social services provides not only vast popular support and seats within Lebanon's current Parliament, but it as well provides future possibilities for increased support, influence and political position.

Possessing a militia was a right granted to LH after Lebanon's 15-year civil war that ended in 1990. While all other militias were ordered to disarm, LH was allowed to keep its weapons and maintain militia operations for the purpose of providing "national resistance" against the Israeli occupation of southern Lebanon. LH maintains its militia capability to this day for that same purpose, namely to oppose Lebanese territories still possessed by Israel (i.e., Shebaa Farms). Opposition to Israeli occupation through militant jihad is the fundamental purpose for which LH possesses and maintains a militia.

LH has stated that its categorical opposition to all attempts to justify the establishment of a Jewish state in Palestine is based on the fact that "changes that have been brought about by history are facts of the past, and every nation in this world has a history that is different from its present" (Qassem, 2005). LH resists Israel to not only reclaim territories under Israeli occupation, but also to restore Islam to prominence by first plucking from its side the Israeli menace – if it were not able to do so, the question for all Muslims and associated organizations would be "How could a tiny Jewish state amass so much military and economic power if the Islamic way of life—not Christianity or Judaism—is God's most ideal religious path?" (Friedman, 2002)

LH is perceived as defending Lebanon by resisting Israel. Doing so legitimizes the right it has been given by Lebanon's government to maintain a militia, which at the same time provides it with a force that no other political party in Lebanon has, all but assuring its survival even by force.

The final key interest of LH, is to gain ultimate control of Lebanese politics and Lebanon's national agenda. Although this power grab is not likely to occur by election in the near future given Lebanon's confessional distribution of parliamentary seats, there is the possibility that LH could one day rise to national prominence. Control of Lebanon might one day be LH's if it is able to continue its growth and further legitimize its purpose and operations beyond their Shi'a constituents.

B.   METHODOLOGY

There are three steps in developing the MDP LH model. First, we develop state trees to capture the interests and feasible actions of stakeholders. We then merge the state trees to form a single influence diagram that captures the interaction of stakeholders and exogenous support. Finally, we implement the influence diagram in a software package.

1.   State Trees

State trees are similar to decision trees. Decision trees are typically horizontal depictions of a set of actions or decisions and their possible consequences. We now show how these probabilistic dependencies are represented by decision trees, and then by state trees, by using a basic scenario known as 'The Party Problem' (Abbas, 2004). The Party Problem was introduced by Ronald A. Howard at Stanford University. In the Party Problem, our stakeholder, in this case a father, wishes to plan a birthday party for his daughter to take place during the coming weekend, which can be held indoors or outdoors. He is not sure if it will be sunny or raining on the day of the party. His daughter's happiness, or rather how much she values the party, therefore depends on the weather and its location:

Value	*Indoors*	*Outdoors*
Rainy	20	−50
Sunny	−20	100

The father has access to a weather forecast. From historical data, he knows that:

$$P(forecastRain \mid Rains) = 0.75$$
$$P(forecastRain \mid Sunny) = 0.15$$
$$P(Sunny) = 0.65$$

We see that the probability of correctly forecasting rain is greater than the probability of incorrectly forecasting rain. The father's information and possible consequences for his decision are depicted in Figure 4.
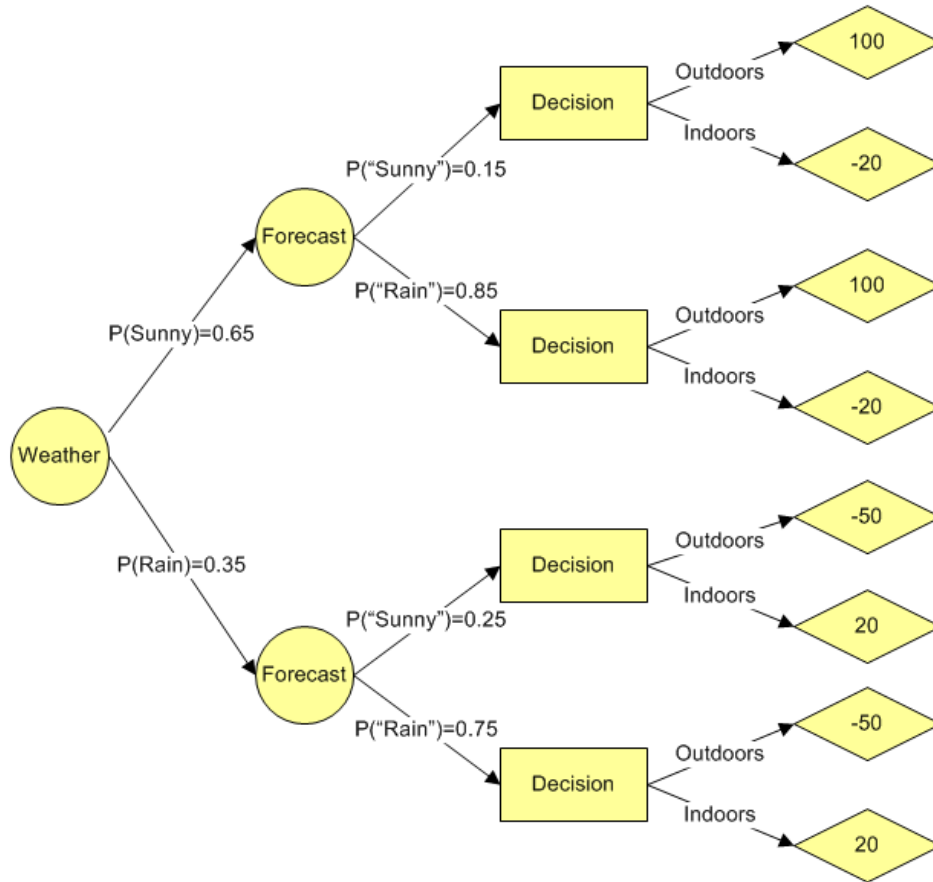
Figure 4.   Basic Decision Tree: "The Party Problem"

The values at the reward nodes (diamond) are computed using Bayes' Theorem, which states:

$$P(A \mid B) = P(B \mid A)\left(\frac{P(A)}{P(B)}\right)$$

We, therefore, have the following:

$$P(Sunny \mid forecastSunny) = \left(\frac{P(forecastSunny \mid Sunny) * P(Sunny)}{P(forecastSunny \mid Sunny) * P(Sunny) + P(forecastSunny \mid Rains) * P(Rains)} \right)$$

$$= \left(\frac{(0.85)(0.65)}{(0.85)(0.65) + (0.25)(0.35)} \right) = 0.863$$

$$P(Rains \mid forecastSunny) = \left(\frac{P(forecastSunny \mid Rains) * P(Rains)}{P(forecastSunny \mid Sunny) * P(Sunny) + P(forecastSunny \mid Rains) * P(Rains)} \right)$$

$$= \left(\frac{(0.25)(0.35)}{(0.85)(0.65) + (0.25)(0.35)} \right) = 0.137$$

$$P(Sunny \mid forecastRain) = \left(\frac{P(forecastRain \mid Sunny) * P(Sunny)}{P(forecastRain \mid Sunny) * P(Sunny) + P(forecastRain \mid Rains) * P(Rains)} \right)$$

$$= \left(\frac{(0.15)(0.65)}{(0.15)(0.65) + (0.75)(0.35)} \right) = .271$$

$$P(Rains \mid forecastRain) = \left(\frac{P(forecastRain \mid Rains) * P(Rains)}{P(forecastRain \mid Sunny) * P(Sunny) + P(forecastRain \mid Rains) * P(Rains)} \right)$$

$$= \left(\frac{(0.75)(0.35)}{(0.15)(0.65) + (0.75)(0.35)} \right) = 0.729$$

Now assessing the situation according to his daughter's happiness, the father calculates the maximum expected value of each of his decisions by:

$$E(Outdoors \mid forecastSunny) = P(Sunny \mid forecastSunny) * Value(Sunny, Outdoors)$$
$$+ P(Rains \mid forecastSunny) * Value(Rain, Outdoors)$$
$$= (0.863)(100) + (0.137)(-50) = 79.45$$

$$E(Indoors \mid forecastSunny) = P(Sunny \mid forecastSunny) * Value(Sunny, Indoors)$$
$$+ (Rains \mid forecastSunny) * Value(Rain, Indoors)$$
$$= (0.863)(-20) + (0.137)(20) = -14.52$$

$$E(Outdoors \mid forecastRain) = P(Sunny \mid forecastSunny) * Value(Sunny, Outdoors)$$
$$+ P(Rains \mid forecastRain) * Value(Rain, Outdoors)$$
$$= (0.271)(100) + (0.729)(-50) = -9.35$$

$$E(Indoors \mid forecastRain) = P(Sunny \mid forecastRain) * Value(Sunny, Indoors)$$
$$+ P(Rains \mid forecastRain) * Value(Rain, Indoors)$$
$$= (0.271)(-20) + (0.729)(20) = 9.16$$

Thus, the father maximizes the value of the party by making the optimal decision to hold the party outdoors if the forecast calls for sunny skies. If the forecast calls for rain, the father maximizes the value of the party by making the optimal decision to hold the party indoors.

State trees are similar in that they depict the set of stakeholder interests and the associated utility values of all feasible combinations of interests. They are sometimes called expected utility models, since their theoretical framework assumes that a stakeholder strives to obtain the largest utility or net gain given their current state in the system. Although a state tree cannot and does not contain the information that decision trees contain, they are often times a good first step in modeling complex networks since they are easier to generate and more explicit in terms of the relationships, hierarchy and values they model.

A state tree can capture the basic elements of the Party Problem. We first consider the stakeholder, who in this case is both the father and his daughter. Next, we identify their primary interests, which are: (1) party location, and (2) weather. This state tree and its hierarchal structure is shown in Figure 5. Weather forecast is a key component in the aforementioned decision tree, but it is not present in the state tree as it is not an interest. Since the weather's forecast is critical information that the father considers, we make special note of this and any other key relationships that might directly or indirectly affect his decision making. Such noted dependencies enable us to transition from a basic state tree to a larger influence diagram in order to capture the full complexity of the Party Problem.
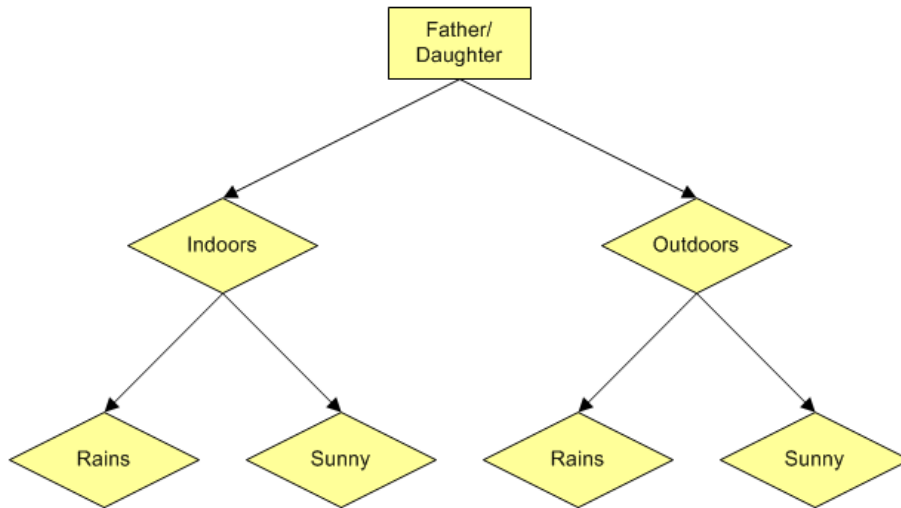
Figure 5.   Basic State Tree: "The Party Problem"

Whereas in Figure 4, utilities are functions of decision and chance, utility calculations are not performed with state trees as shown in Figure 5. Rather, the utilities of each combination of stakeholder interests, called the state space, are explicitly assigned.   In Figure 5, interesting dynamics of how the daughter's happiness might be assigned by the father are quickly explored, such as in the following instance:

$$value_x \geq value_y$$
$$value_x = [Indoors \cap Sunny]$$
$$value_y = [Outdoors \cap Rains]$$

This shows that having the party indoors notwithstanding sunny skies is valued more than having the party outdoors with rain.

The Party Problem illustrates the concepts that we now apply in modeling the LH question. The interests of LH were identified through a series of meetings and other formal correspondence with anthropologists, economists, intelligence analysts and various other SMEs made available by the UCC for the development of this study. The identified interests can be economic, diplomatic, political, social or even religious in nature.

The state tree in Figure 6 models the interests of the primary stakeholder for this thesis (LH). The information contained therein is the combination of the expressed belief of the UCC's SMEs and the interpretation by this author of the historical literature reviewed. Five key interests are identified for LH, and while they are not listed in any sort of hierarchal or priority order, the most fundamental interests tended to percolate to the top of the tree each time we attempted to frame the sequence of possible interest combinations. A value, ranging from 0 to 100, is assigned for each combination of interest(s), essentially meaning that *'if LH had 100 dollars to spend, the number shown is how much they would pay to live in a world wherein such combinations were and/or were not realized.'* The interests of LH are defined and discussed in the previous Data section and can be found in the Glossary of Terms.
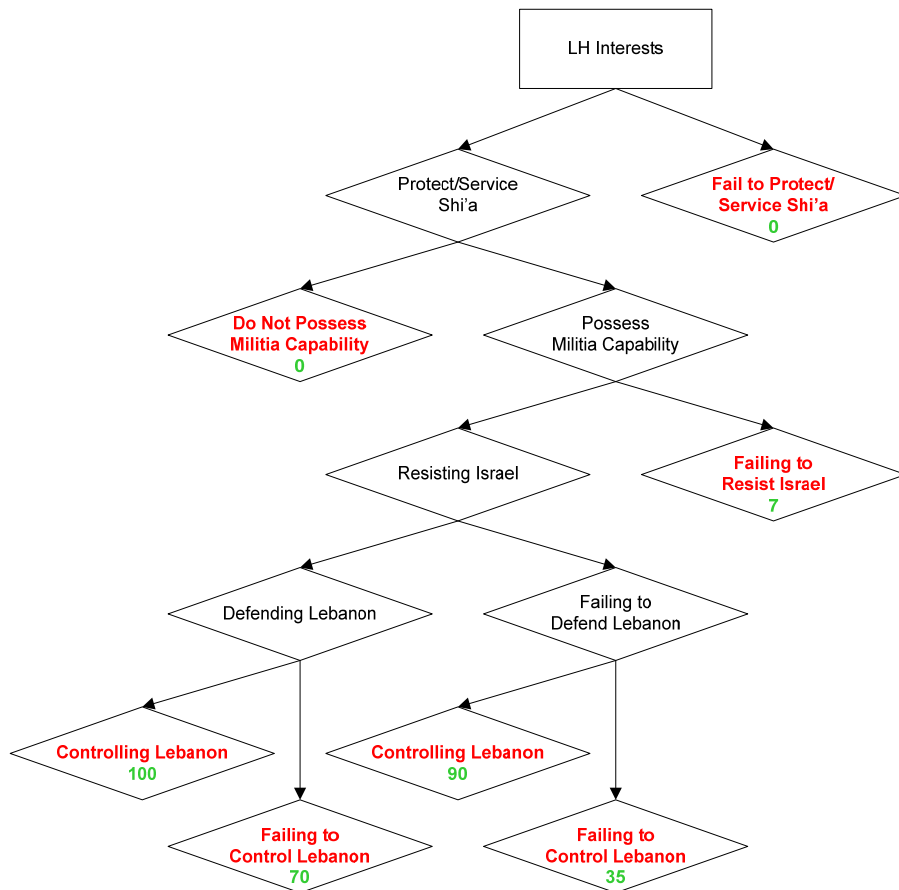
Figure 6.   LH State Tree

29

2.   Influence Diagrams

Influence Diagrams (ID) are a relatively new method for representing probabilistic dependencies in decision analysis (Howard and Matheson, 2005). The ID is an alternative to the use of decision trees and state trees for depicting decision or interest situations. It is "at once both a formal description of the problem that can be treated by computers and a representation easily understood by people in all walks of life and degrees of technical proficiency. It forms a bridge between qualitative description and quantitative specification" (Howard and Matheson, 2005). Figure 7 depicts how various elements of a decision situation are represented in IDs:
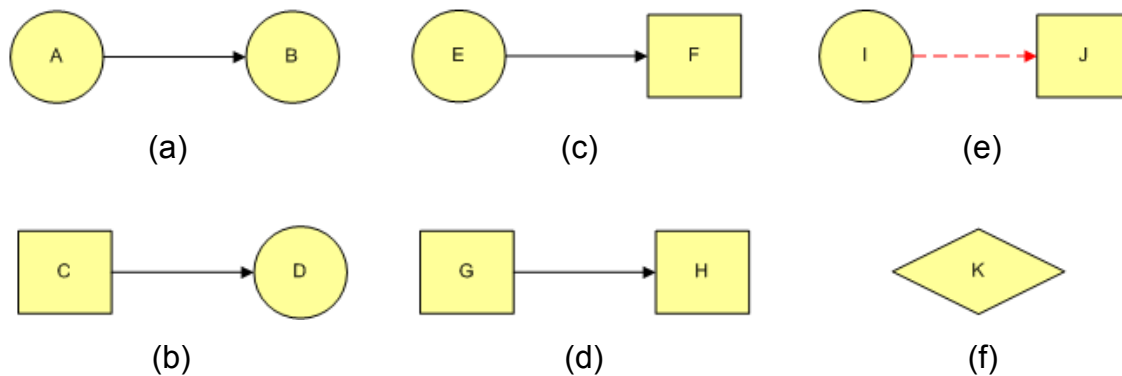
Figure 7.   ID definitions

Chance variables are represented by circles, *decisions* by square/rectangles, and *interests* by diamonds. Figure 7a shows that the probabilities associated with "B depends on the outcome of A". Figure 7b depicts how the probabilities associated with "D depends on decision C". In Figure 7c, the decision at F is made with the knowledge of the outcome at E. In Figure 7d, the decision at H is made knowing what decision at G was made. Finally, the dotted arc in Figure 7e depicts a temporal relationship the chance variable I influences the next time step's decision made at J. An example of an interest, the calculation of a value or utility, is shown at K in Figure 7f. The terms defined by the graphical representations of chance, decision, and interest are called nodes.

Decision, interest, and chance nodes are connected to model a Bayesian network that can solve for expected utilities given mapped interactions. An influence diagram that models the aforementioned "Party Problem" is shown in Figure 8.
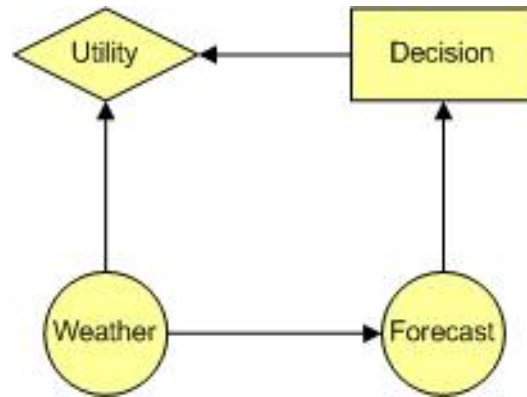
Figure 8.   Basic Influence Diagram: "The Party Problem"

The forecast probabilistically depends on the weather. The father's decision as to where the party will be held, is made after receiving the forecast. The resulting measure of his daughter's happiness, as calculated in the decision tree and similarly captured in Figure 8, is a value that depends on the party's location and actual weather.

3.   The LH Influence Diagram

LH is the main stakeholder and sole decision maker. Secondary participants are the Lebanese Diaspora, and Lebanese people. The influence diagram shown in Figure 9 contains three decision nodes (rectangles), four chance nodes (circles), and an interest (or value) node (diamond).

Figure 9.   Complete Influence Diagram

Each decision node contains a set of actions related to the rectangle's classifier. The three decision nodes contain the following feasible LH actions, as identified by the UCC's SMEs:

Diplomacy/Econ/Finance: *Develop closer relationship with Iran*
Increase political maneuvering

Information/Intelligence: *Increase outreach to Diaspora*
Expand goods/services beyond Shi'a

Military/Law Enforcement: *Provoke or attack Israel*
Increase illicit actions
Sponsor or conduct a terrorist attack
Increase support to Hamas

The top-most decision node, Diplomacy/Econ/Finance, represents 'soft' decisions that may be made with knowledge about popular support for LH within Lebanon, Lebanese people in the Diaspora, and past Syrian actions. The second decision node, Information/Intelligence, focuses on decisions related to LH's intelligence apparatus; once more, this kind of decision is taken with some noisy information about Syria's past actions and knowledge regarding popular support for LH within Lebanon. The last decision node, Military/Law Enforcement, deals with military acts inside and outside Lebanon. LH makes these decisions with some information about popular support for LH within Lebanon and with some information about the previous military action's outcome.

The chance node "LB PopSpt" concerns the Lebanese popular opinion vis-à-vis LH's decision situation. The popular opinion in Lebanon may be probabilistically dependant on LH's decisions (arrows going from the rectangles to the circle), and on the result of military actions (if any). The influence of the Lebanese Diaspora on popular opinion within Lebanon may be probabilistically dependant on LH's diplomatic actions. Also, any military outcome may shape subsequent political and economic support provided by the Lebanese Diaspora to the Lebanese populace.

The last important element is the value node, which depends on the result of popular support within Lebanon for LH, and the Diaspora's support for LH. The value to LH corresponding to each possible outcome is derived from past discussions during our meetings with the UCC.

The abridged influence diagram, shown in Figure 10, is easier to implement and still captures the key aspects of the decision situation. The main difference in relation to the complete version is that the decisions have been collapsed into one big decision node. We still can input arbitrary combinations of decisions during model implementation, so no validity is lost.
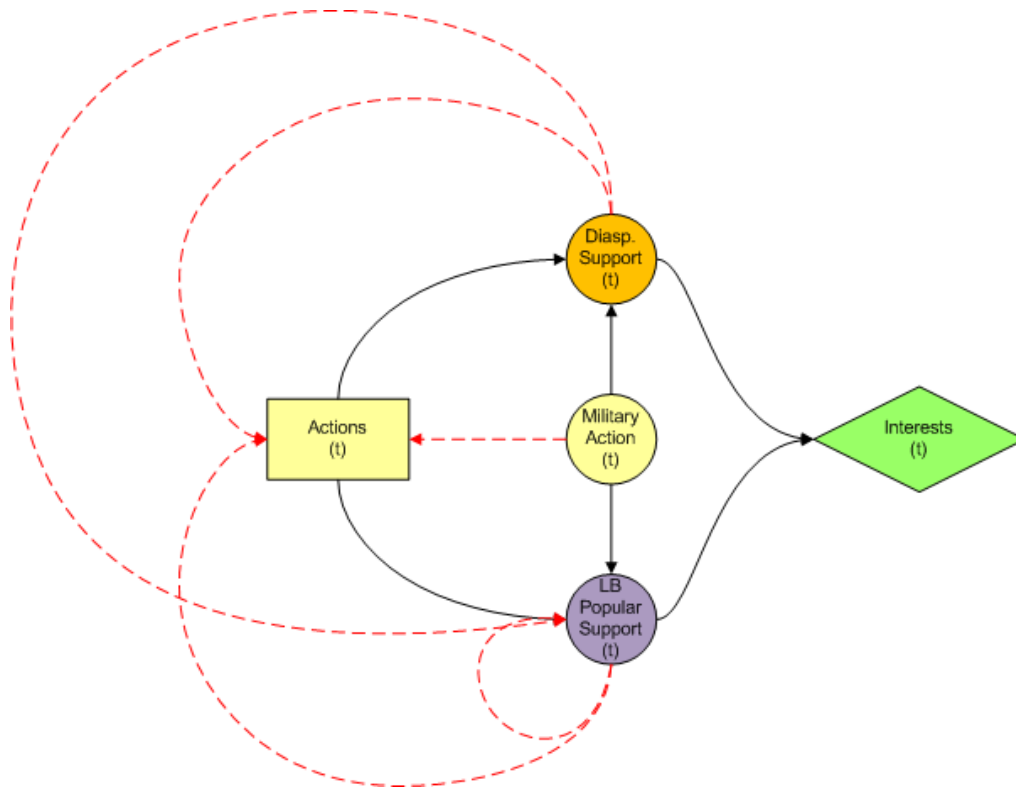
Figure 10.   Abridged Influence Diagram

While much work was done by the author, advisors, and SMEs, to lay the groundwork for a dynamic model that captures the interests, decisions and interactions of two stakeholders and their exogenous support, in a single state space, no formal modeling or analysis is done in this thesis for a scenario involving multiple stakeholders. These multi-player game model diagrams would result from questions such as: *How will Syria's potential/likely decisions and actions affect their relationship with LH?* The IDs shown in Figures 11 and 12 were developed to answer the LH and Syria question, using the same methodology, meticulous detail, dialog and SME review as the LH diagram:
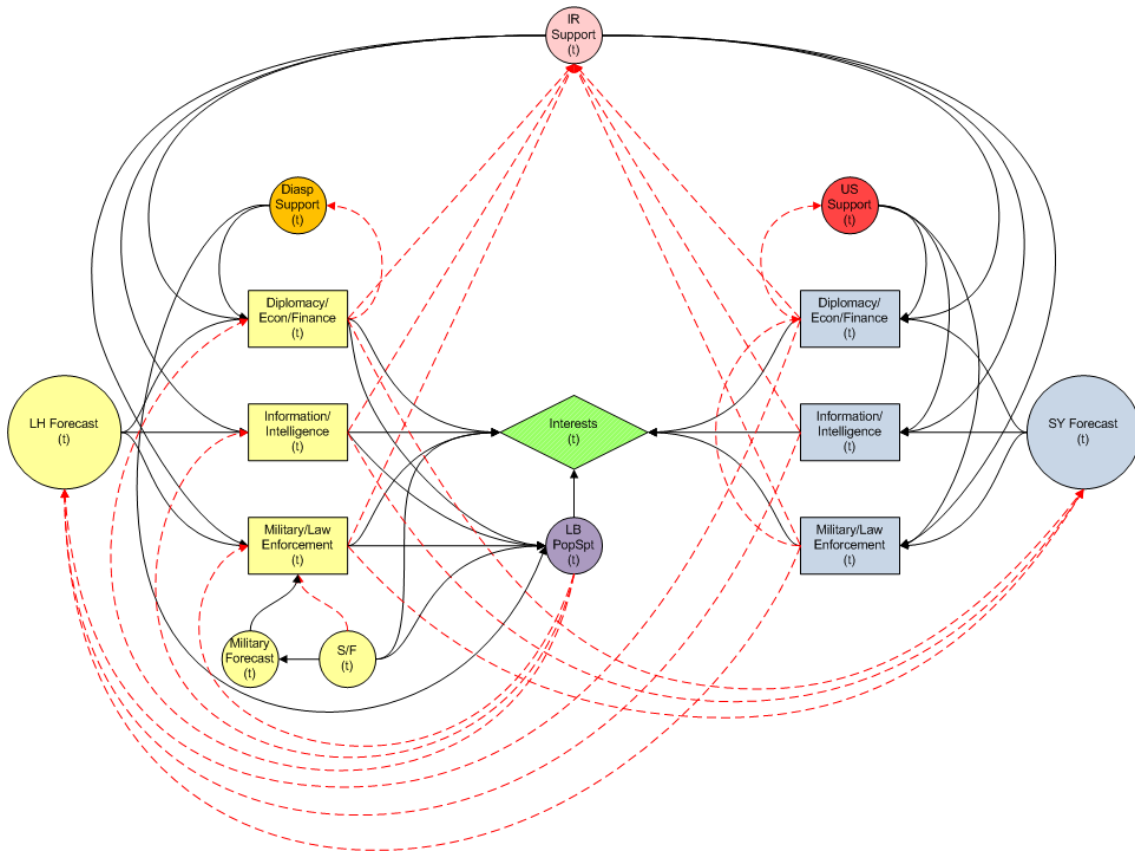
Figure 11.   Complete LH and Syria Influence Diagram
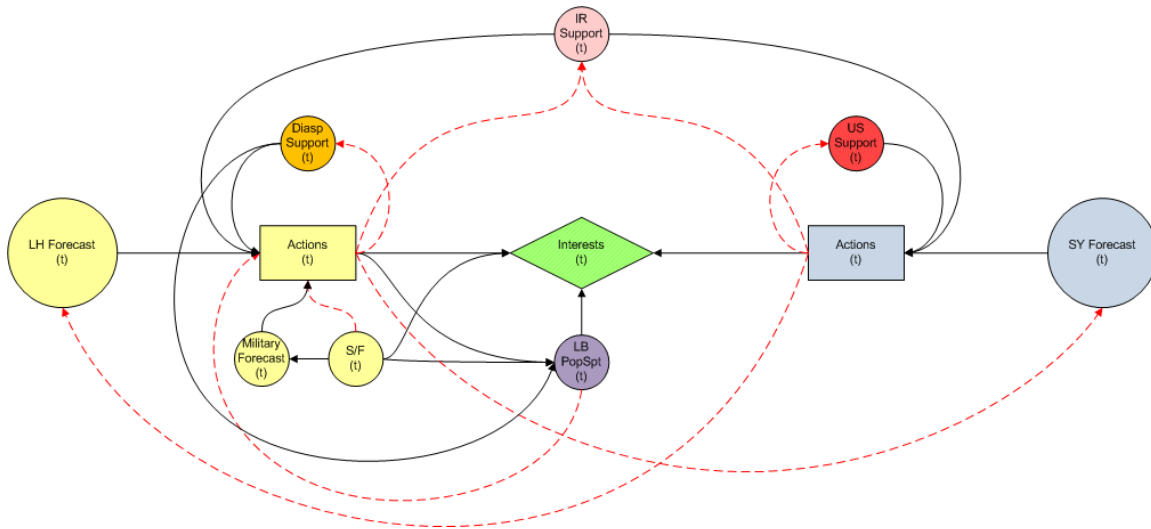
Figure 12.   Abridged LH and Syria Influence Diagram

The models shown in Figures 11 and 12 assume that each stakeholder has interests and a reward he is trying to maximize through taking a sequence of actions determined by his forecast of the other stakeholder, as well as the contemporary actions of relevant exogenous support and the previous slice's actions of the other stakeholder. Research and an eventual model to this end would prove useful in modeling many types of stakeholder interdependencies, and could as well lay the foundation for increasing the number of 'participants in the game' to well beyond two stakeholders—a point at which exogenous support is modeled fully with their own interests, actions and rewards, rather than probabilistic chance nodes.

C. IMPLEMENTATION

1. GeNIe Implementation

The influence diagram is implemented in GeNIe by explicitly creating chance nodes for every LH interest. These interest nodes map to a single reward node. The dimension of time is created by mapping previous chance nodes to future iterations of the same influence diagram, which effectually makes each successive network dependent on the previous network. Figure 13 depicts a single layer of the full influence diagram, and contains only those nodes with temporal relationships, making the full implementation a DBN.
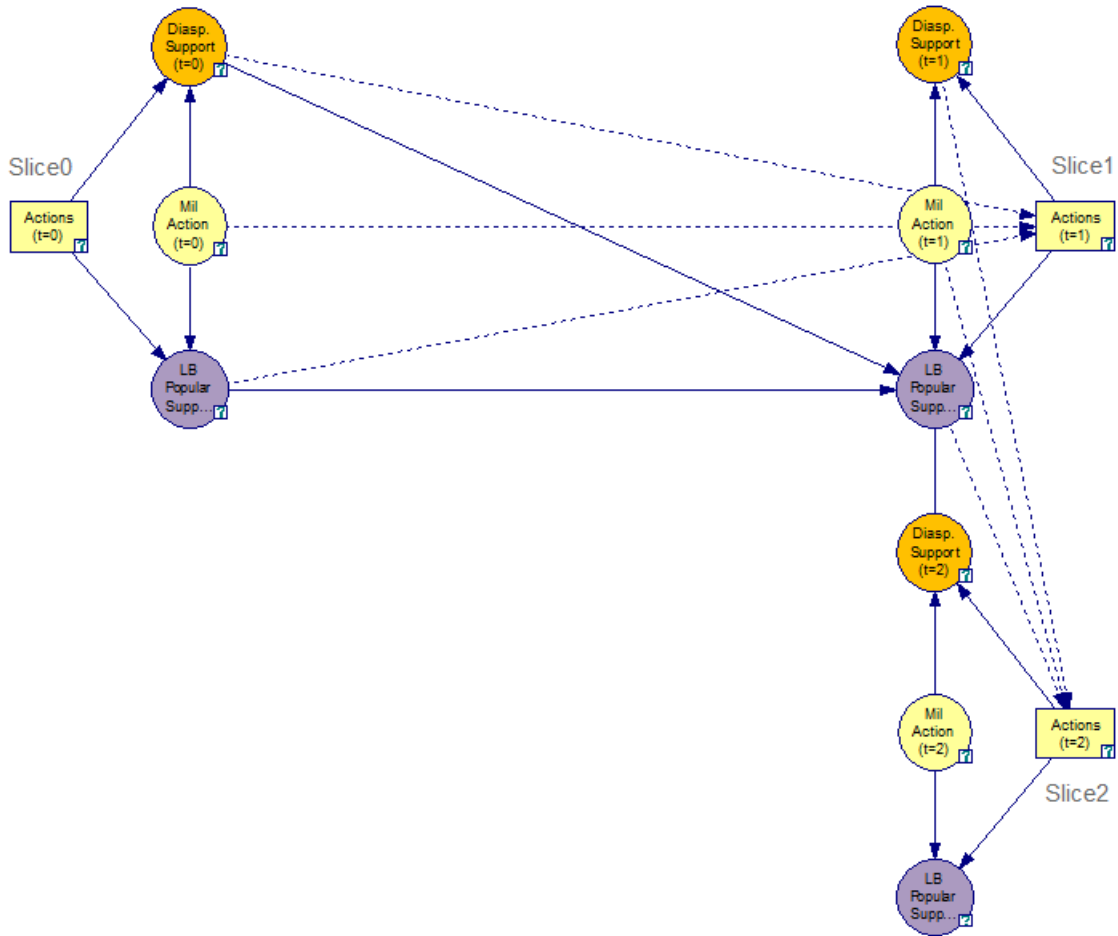
Figure 13.   Temporal relationships in the GeNIe implementation

As seen in Figure 13, each period of time (or iteration) of the influence diagram is called a slice. Each slice represents one time period, which for all intents and purposes of this study is approximated as being equal to one year.

The full implementation of the LH model is shown in Figure 14, where five independent interest (chance) nodes are added to the network, which is how the complexity of $2^{5+5+5}=2^{15}$ interest combinations is added.
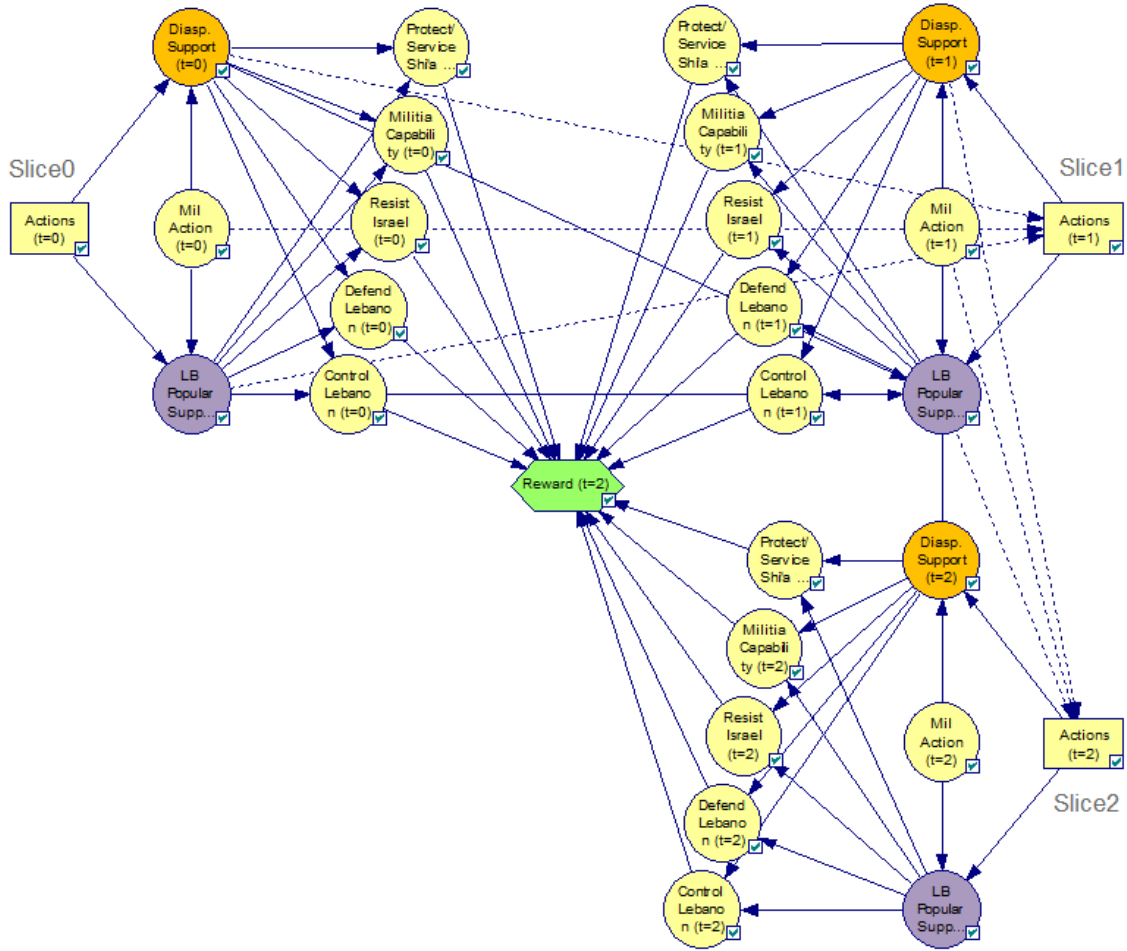
Figure 14.   Full GeNIe implementation

Each slice contains eight chance nodes, but are interest nodes for a total of 15 interest chance nodes mapping into a single reward node in the full influence diagram. For the purpose of scalability, these chance nodes are binary, and thus we have 2^{15} possible interest combinations. In GeNIe, users are required to assign values to each interest combination. With 32,768 possible interest combinations, it is necessary for us to simplify the task of computing these values. A software tool, scripted by the author in VBA and named *DMAPS: A Dynamic Model for the Analysis of Political Stakeholders*, does this for us by summing the user-assigned values for each interest across the set of all possible interest combinations.

DMAPS prompts the user to assign a value to the realization or absence of each interest. These values are then automatically varied to provide the user with a total of 11 possible value combinations (called scenarios) from which they can elect to evaluate their model as shown in Figure 15. Multiple scenarios allow the user to gain insight through sensitivity analysis.

User Input: Values and Distributions

| Select scenario for values of interest combinations: | 1.0 |
| Select scenario for chance node distributions: | 3.5b |

Generate Output Values   Help

Slice	Interest	Current Values Yes	Current Values No
0	Control Lebanon	5	-5
	Defend Lebanon	20	-20
	Resist Israel	50	-50
	Militia Capability	90	-90
	Protect/Svc Shi'a	100	-100
1	Control Lebanon	40	-40
	Defend Lebanon	50	-50
	Resist Israel	40	-40
	Militia Capability	70	-70
	Protect/Svc Shi'a	100	-100
2	Control Lebanon	50	-50
	Defend Lebanon	60	-60
	Resist Israel	30	-30
	Militia Capability	50	-50
	Protect/Svc Shi'a	100	-100

Slice	Interest		Current Interest Distributions			
			Diasp Spt LH		Not	
			LB Spt LH	Not	LB Spt LH	Not
All	Control Lebanon	Control	0.90	0.65	0.85	0.50
		Not	0.10	0.35	0.15	0.50
	Defend Lebanon	Defend	1.00	0.70	0.90	0.50
		Not	0.00	0.30	0.10	0.50
	Resist Israel	Resist	0.95	0.80	0.60	0.50
		Not	0.05	0.20	0.40	0.50
	Militia Capability	Possess	1.00	0.90	0.70	0.50
		Not	0.00	0.10	0.30	0.50
	Protect/Svc Shi'a	Provide	1.00	0.70	0.80	0.60
		Not	0.00	0.30	0.20	0.40

Figure 15.   DMAPS user prompt for the assignment of interest values

Notice that each interest is associated with the model's 'three slices' which are representative of the discrete time period (three years) for which this thesis investigates. The user can choose to evolve the worth of interests for LH by assigning increasing or decreasing values for each interest according to their associated slice. This evolution of interests captures the fact that, say, if LH intends to become a more legitimate political entity, through the progression of each slice of the model, it must maintain its focus and value of protecting and providing services to the Shi'a, increase the value associated with controlling Lebanon, and decrease the importance it associates with resisting Israel outright.

Using DMAPS not only benefits the user by assisting with the assignment of values for every combination of interests, but it also ensures the user populates the model's full laundry list of all required distributions. It has also

been designed to provide useful tools for the user such as prompts, help icons, and auto-population formulae that reduce the time and error associated with user interface.

2. Required Data

Data relating to the interests, actions, values and distributions were obtained through discussions with the UCC's SMEs.

After having determined the scope of the LH question, which identified the critical components for our ID (namely the stakeholders, exogenous support, interests and actions), data was collected and reviewed in order to assign both realistic and notional values to the model's 361 variable fields (see Table 1). The somewhat tedious process is reduced through the use of DMAPS which automatically calculates the compliment of every initial distribution provided by the user, reducing data entry from 361 fields to just 197. The logic used to identify these 361 fields is discussed in Chapter III, Section C.2.b. The efficiency of using the DMAPS interface is shown in Table 1.

Variable	Fields	Fields with DMAPS
Values assigned to LH's interests (all)	30	30
Distribution of LH's interests (all)	40	20
Distribution of Diasp Spt (all)	48	24
Distribution of LB Pop Spt (t=0)	48	24
Distribution of LB Pop Spt (t=1,2)	192	96
Distribution of Military Action (all)	3	3
Total	361	197

Table 1.   Efficiencies of DMAPS pertaining to user interface

The values and distributions assigned to the fields shown in Table 1 were determined through an iterative process shown in Figure 16.
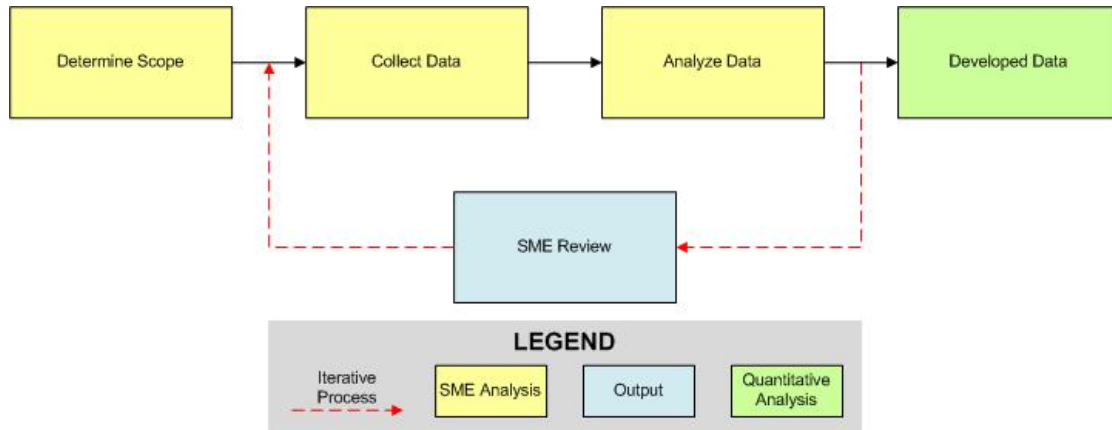
Figure 16.   Data Development

a.   *Values*

Table 2 contains the values assigned to each LH interest across the model's three slices. An interest can be assigned a different, or evolving, value to capture the fact that LH might value said interest more or less in the future based on its desires to become a larger part of the Lebanese political process. We use, from Table 2, the example of the interest 'Militia Capability'. We see that the 'current' value, or t=0, which LH associates with possessing a militia capability is ± 90 (on a scale 0 to 100). The value of this interest decreases to ± 70 in t=2, and again to ± 50 in t=3, representative of the SME analysis that as LH seeks to become a larger part of the Lebanese political process, its emphasis on maintaining and employing a militia must be reduced.

Slice	Interest	Yes	No
0	Control Lebanon	5	-5
	Defend Lebanon	20	-20
	Resist Isreal	50	-50
	Militia Capability	90	-90
	Protect/Svc Shi'a	100	-100
1	Control Lebanon	40	-40
	Defend Lebanon	50	-50
	Resist Isreal	40	-40
	Militia Capability	70	-70
	Protect/Svc Shi'a	100	-100
2	Control Lebanon	50	-50
	Defend Lebanon	60	-60
	Resist Isreal	30	-30
	Militia Capability	50	-50
	Protect/Svc Shi'a	100	-100

Table 2.   Values assigned to LH interests

b.   Distributions

From the GeNIe implementation, we can visually deduce the number of distributions contained within our model. In each slice, we see that there is one decision node, two exogenous actor chance nodes, 2 LH military action chance nodes, and 5 LH interest chance nodes.   The number of distributions contained within each of these chance nodes is determined by the permutation of its own distributed outcomes and the outcomes of its antecedent chance and/or decision nodes.   From Figure 13, we see that the number of distributions, contained in each chance node, are summarized in Table 3.

Chance Node	Antecedents	Number of Distributions
LH Interests (all)	Diasp Spt LB Pop Spt	(2 Diasp Spt)(2 LB Pop Spt)* (5 LH Interests) = 20
Diasp Spt (all)	Actions Mil Action	(3 Mil Action)(8Actions) = 24
LB Pop Spt (t-0)	Actions Mil Action	(3 Mil Action)(8 Actions) = 24
LB Pop Spt (t-1,2)	Actions Mil Action	(3 Mil Action)(8 Actions)* (2 Diasp Spt)(2 LB Pop Spt) = 96
Mil Action (all)	None	3

Table 3.   Efficiencies of DMAPS pertaining to user interface

The 361 user populated fields discussed in Chapter III, Section C.2 is the sum of the product of each LH interest chance node having a binomial outcome, 3 potential outcomes in the Military Action chance node, and 30 values explicitly assigned to each LH interest.

$$(20+24+24+96)(2)+3+20 = 361$$

The distributions assigned at each chance node in this model are based on data provided by the UCC's SMEs. Due to the number and length of said distributions, readers may request access to the author's version of DMAPS for information on the values assigned to each of the model's distributions.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. ANALYSIS

A. RESULTS

As we model how LH might decrease its use of internal/external violence in an attempt to become a larger part of the political process, our ID calculates the expected reward associated with each feasible outcome to the system for each scenario run. In order to scale the results and conduct reasonable analysis, we take the average reward per scenario to determine their deviation from their respective **base case scenario**. Each non-base case scenario is generated by DMAPS after the user has entered his user-specified values for each LH interest. Then, for the purpose of sensitivity analysis, DMAPS iteratively varies the values of each LH interest first by a multiple of $\pm 1/2$ (a), then by a multiple of $\pm 3/2$ (b). These generated scenarios, in addition to the user-specified scenario, provide us with results useful to sensitivity analysis.

1. Scenario 1

First, we will investigate a base case scenario (Scenario 1) where the values of each interest are based on data provided by the UCC's SMEs. DMAPS generates ten subsequent scenarios based on Scenario 1. Tables 4 and 5 contain the values for the interests of Scenarios 1.

Slice	Interest	Yes (1.0)	No (1.0)
0	Control Lebanon	5	-5
	Defend Lebanon	20	-20
	Resist Israel	50	-50
	Militia Capability	90	-90
	Protect/Svc Shi'a	100	-100
1	Control Lebanon	40	-40
	Defend Lebanon	50	-50
	Resist Israel	40	-40
	Militia Capability	70	-70
	Protect/Svc Shi'a	100	-100
2	Control Lebanon	50	-50
	Defend Lebanon	60	-60
	Resist Israel	30	-30
	Militia Capability	50	-50
	Protect/Svc Shi'a	100	-100

Table 4.   User-specified Scenario 1 (base case for Scenarios 1)

Slice	Interest	1.1a Yes	1.1a No	1.1b Yes	1.1b No	1.2a Yes	1.2a No	1.2b Yes	1.2b No	1.3a Yes	1.3a No
0	Control Lebanon	5	-5	5	-5	5	-5	5	-5	5	-5
	Defend Lebanon	20	-20	20	-20	20	-20	20	-20	20	-20
	Resist Israel	50	-50	50	-50	50	-50	50	-50	25	-25
	Militia Capability	90	-90	90	-90	45	-45	135	-135	90	-90
	Protect/Svc Shi'a	50	-50	150	-150	100	-100	100	-100	100	-100
1	Control Lebanon	40	-40	40	-40	40	-40	40	-40	40	-40
	Defend Lebanon	50	-50	50	-50	50	-50	50	-50	50	-50
	Resist Israel	40	-40	40	-40	40	-40	40	-40	20	-20
	Militia Capability	70	-70	70	-70	35	-35	105	-105	70	-70
	Protect/Svc Shi'a	50	-50	150	-150	100	-100	100	-100	100	-100
2	Control Lebanon	50	-50	50	-50	50	-50	50	-50	50	-50
	Defend Lebanon	60	-60	60	-60	60	-60	60	-60	60	-60
	Resist Israel	30	-30	30	-30	30	-30	30	-30	15	-15
	Militia Capability	50	-50	50	-50	25	-25	75	-75	50	-50
	Protect/Svc Shi'a	50	-50	150	-150	100	-100	100	-100	100	-100
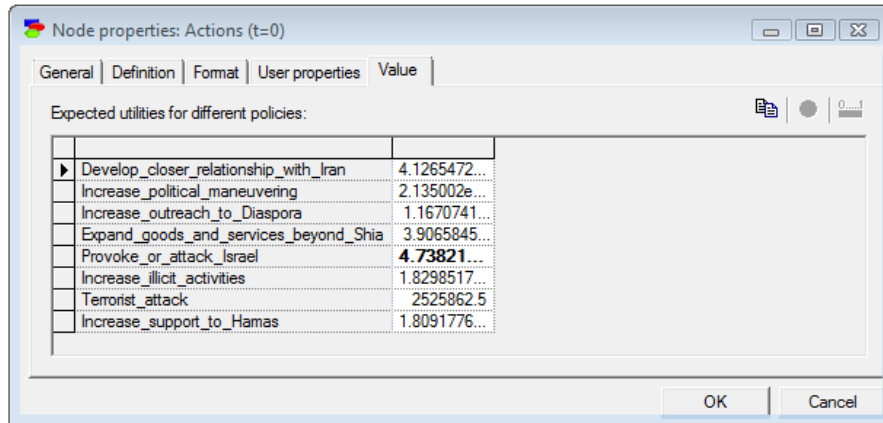
Slice	Interest	1.3b Yes	1.3b No	1.4a Yes	1.4a No	1.4b Yes	1.4b No	1.5a Yes	1.5a No	1.5b Yes	1.5b No
0	Control Lebanon	5	-5	5	-5	5	-5	2.5	-2.5	7.5	-7.5
	Defend Lebanon	20	-20	10	-10	30	-30	20	-20	20	-20
	Resist Israel	75	-75	50	-50	50	-50	50	-50	50	-50
	Militia Capability	90	-90	90	-90	90	-90	90	-90	90	-90
	Protect/Svc Shi'a	100	-100	100	-100	100	-100	100	-100	100	-100
1	Control Lebanon	40	-40	40	-40	40	-40	20	-20	60	-60
	Defend Lebanon	50	-50	25	-25	75	-75	50	-50	50	-50
	Resist Israel	60	-60	40	-40	40	-40	40	-40	40	-40
	Militia Capability	70	-70	70	-70	70	-70	70	-70	70	-70
	Protect/Svc Shi'a	100	-100	100	-100	100	-100	100	-100	100	-100
2	Control Lebanon	50	-50	50	-50	50	-50	25	-25	75	-75
	Defend Lebanon	60	-60	30	-30	90	-90	60	-60	60	-60
	Resist Israel	45	-45	30	-30	30	-30	30	-30	30	-30
	Militia Capability	50	-50	50	-50	50	-50	50	-50	50	-50
	Protect/Svc Shi'a	100	-100	100	-100	100	-100	100	-100	100	-100

Table 5.   User-specified Scenario 1 (base case for Scenarios 1)

Each of these value distributions generate a single array (1 x 32,768) containing the sum of all possible combinations of interests. GeNIe then solves the network based on the user specified interest combination values and distributions at each chance node.
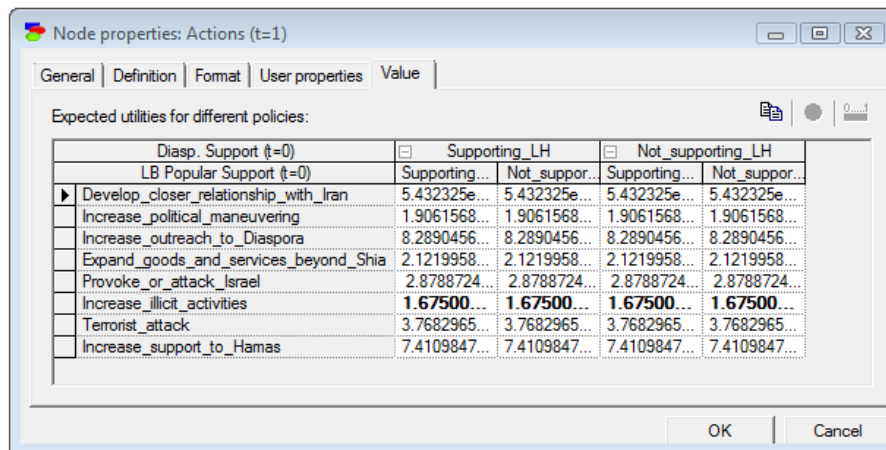
The values in Scenario 1 provide us with a base case that is representative of the most realistic forecast of future LH actions, given our assumption of accuracy of the SME data. As we are interested in knowing the LH's optimal strategy (what actions LH might take during each slice, or time step), we refer to the values calculated by GeNIe at the decision nodes for each action.

Tables 6–9 contain the calculated values for the LH's potential actions at t=0,1,2:

Table 6.   Scenario 1 optimizing action at t=0: Provoke or attack Israel

Table 7.   Scenario 1 optimizing action at t=1: Increase illicit activities

Table 8.   Scenario 1 optimizing action at t=2

Diasp. Support (t=0)					Supporting_LH	
LB Popular Support (t=0)			Supporting_LH			
Diasp. Support (t=1)		Supporting_LH		Not_supporting_LH		St
LB Popular Support (t=1)	Supporting...	Not_suppor...	Supporting...	Not_suppor...	Supporti...
Develop_closer_relationship_with_Iran	789.2458	**602.01113**	**628.4674**	**420.41854**	586.45
Increase_political_maneuvering	781.58526	595.22766	621.23658	413.95025	578.99
Increase_outreach_to_Diaspora	**789.98516**	601.30543	628.45048	419.1413	**586.97**
Expand_goods_and_services_beyond_Shia	785.777	599.3707	625.41995	418.08874	583.14
Provoke_or_attack_Israel	769.87513	583.93042	609.69402	402.79908	567.39
Increase_illicit_activities	755.87598	570.79584	596.08996	389.98916	553.58
Terrorist_attack	760.46554	574.42407	600.19527	393.21467	558.05
Increase_support_to_Hamas	763.07758	577.31273	602.96282	396.23295	560.67

Table 9.   Scenario 1 reward node

Protect/Servic...								
Militia Capabilit...								
Resist Israel (t...								
Defend Leban...								
Control Leban...								
Protect/Servic...								
Militia Capabilit...								
Resist Israel (t...								
Defend Leban...								
Control Leban...								
Protect/Servic...								
Militia Capabilit...					Possess_Militia			
Resist Israel (t...		Resisting_IS				Not_Resisting_IS		
Defend Leban...		Defending_LB		Not_Defending_LB		Defending_LB		Not_De
Control Leban...	Controlling_...	Not_Contro...	Controlling_...	Not_Contro...	Controlling_...	Not_Contro...	Controlling_
Value	957	950	917	910	857	850	81

The optimal strategy, or action, calculated by GeNIe suggests that in the first slice, LH would maximize its expected reward by "provoking or attacking Israel." In the second slice, no matter how the state space transitioned after the first slice, LH would invariably maximize its expected reward by "increasing illicit activities." It is not until the third slice that we see (truncated in Table 8) that LH would maximize its reward by taking an action conditional on the state space

after the first and second slices. There are just two optimizing actions at t=2. Its optimal strategy, given the state of the system at t=2 would be to either "increase outreach to the Diaspora" or "develop a closer relationship with Iran."

The reward node calculates the set of all optimal strategies, and shows (truncated in Table 9) that LH's optimizing action after t=2, would have been to "develop a closer relationship with Iran." Closer investigation of the reward node reveals that there are 128 feasible combinations of actions in slice 2 that LH could take following the resultant combination of LB Popular Support and Diaspora Support from t=0,1. These 128 feasible combinations are grouped into 16 sets based on the binary nature of LB Popular Support and Diaspora support for each slice:

$$(2 DiaspSpt_1)(2 DiaspSpt_2)(2 LBPopSpt_1)(2 LBPopSpt_2) = 16 \; sets$$
$$(2 DiaspSpt_1)(2 DiaspSpt_2)(2 LBPopSpt_1)(2 LBPopSpt_2)(8 Actions) = 128 \; feasible \; combinations$$

For each of the 16 sets, the maximum value of the set is the optimizing action that LH should take in t=2. For example, in a state where the Lebanese Diaspora was supporting LH in t=0, Lebanese Popular Opinion is supporting LH in t=0, but Lebanese Diaspora is not supporting LH in t=1, and Lebanese Popular Opinion is also not supporting LH in t=1, then the optimal strategy or action for LH to take would be to "develop a closer relationship with Iran" with a reward value of 419. Table 10 orders actions according to their forecasted reward, given the aforementioned state space.

Reward	Action
419	Develop closer relationship with Iran
416	Increase outreach to Diaspora
401	Increase political maneuvering
396	Provoke or attack Israel
388	Expand goods and services beyond Shia
376	Increase illicit activities
368	Sponsor or conduct a terrorist attack
365	Increase support to Hamas

Table 10.   Ordered rewards for the given state space.

Due to the number of sets (16) and the number of values calculated for actions within each set (128), readers may contact the author to request a copy of DMAPS to view the full summary of the optimal strategies.

Every generated variant of Scenario 1, with the exception of Scenario 1.1a, share the same optimal strategy. Maximizing LH's reward after t=2 clearly has negative connotations for improved relations with Israel and the West as seen in the summary of optimal strategies:

Scenario 1: Optimal LH Strategy
t=0: Provoke or attack Israel
t=1: Increase illicit activities
t=2: Develop closer relationship with Iran

Varying the interest's values changed the optimal strategy exclusively in 1.1, where the optimal strategy for 15 of its 16 possible states after t=2 is to "increase outreach to the Diaspora"–the one exception being "develop closer relationship with Iran."   These results provide a strong forecast that (per the values, distributions and design of the model) LH is likely to maximize its reward by pursuing strategies unfavorable to Israel and the West in their quest to become a larger part of the Lebanese political process.

B.   SENSITIVITY ANALYSIS

Sensitivity analysis helps us determine what interests and exogenous support significantly influence the reward the model calculates for LH as it seeks to become a larger part of the Lebanese political process. By understanding which of these are most important, we can suggest that these aspects of the model and current situation ought to receive special attention of policy makers and strategists. The focused efforts of the state and defense departments would allow the U.S. and its allies to manipulate pressures to key actors and interests that would yield an outcome to the state space more favorable to Israel and the West.

1.   Scenario 1

The impetus for varying each interest off the base case scenario to provide us with 10 alternate scenarios should now be evident. We will be able to discern graphically which attributes of the model matter most through the application of ***tornado diagrams***. Table 11 contains the average reward for each scenario, with each value depicted using a standard 'heat scale'.

Scenario	1.0	1.1a	1.1b	1.2a	1.2b	1.3a	1.3b	1.4a	1.4b	1.5a	1.5b
Average	401	316	486	339	461	373	428	370	432	406	397
Max	721	585	857	628	812	674	767	663	779	694	749
Min	78	35	122	49	107	68	89	78	79	124	33

Table 11.   Scenario 1 results

These results show that Scenarios 1.1a and 1.1b, wherein the interest of "protecting and providing services to the Shi'a within Lebanon" was varied, resulted in the most varied average expected payoff. Scenarios 1.2a and 1.3b, relating to LH's "militia capability," are next in the order of magnitude difference from the base case.

We could continue our logic to intuitively identify the relative importance of each interest in Scenario 1, however, we will now employ the aforementioned tornado diagram. In a tornado diagram, the length of the bar corresponding to each interest represents the extent to which the difference between expected payoffs is sensitive to the interest's value as a variable. The interest that is most sensitive to variation corresponds to that with longest bar span. The least sensitive variable has the shortest bar span.
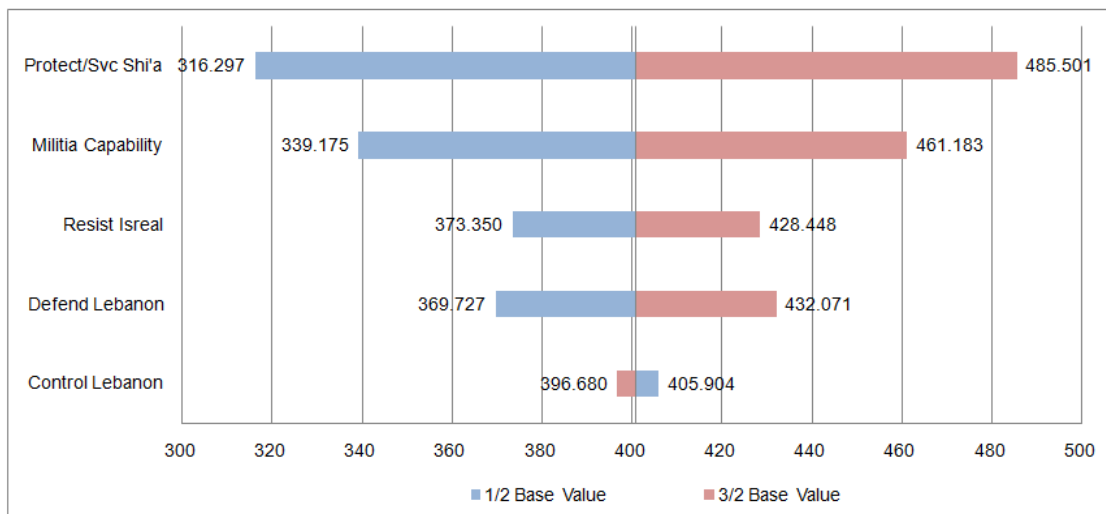
Figure 17.   Tornado diagram for Scenarios 1

From Figure 17's plot of Scenario 1 and its variants, we can see that the difference between expected payoffs varies most greatly according to the value assigned to LH's interest of "protecting and providing services to the Shi'a throughout Lebanon." The fact that this interest is the most material variable in terms of payoff is not altogether surprising, based on the opinions of the SMEs and where it was placed in the hierarchy of LH State Tree (first split in Figure 1).

2.   Scenario 2

In the base case for the second set of scenarios, the values of each interest in every slice are equally important to LH. Thus, all values for all interests are equal in the base case, then varied iteratively thereafter. This is

done to part from reality and evenly assess the interaction of distributions with the values of interests. The remaining 10 scenarios vary from their base case identically as in the case of scenario 1 and are shown in the data Tables 12 and 13.

Slice	Interest	2.0 Yes	2.0 No
0	Control Lebanon	100	-100
	Defend Lebanon	100	-100
	Resist Israel	100	-100
	Militia Capability	100	-100
	Protect/Svc Shi'a	100	-100
1	Control Lebanon	100	-100
	Defend Lebanon	100	-100
	Resist Israel	100	-100
	Militia Capability	100	-100
	Protect/Svc Shi'a	100	-100
2	Control Lebanon	100	-100
	Defend Lebanon	100	-100
	Resist Israel	100	-100
	Militia Capability	100	-100
	Protect/Svc Shi'a	100	-100

Table 12.   Scenario 2 (base case for Scenario 2)

Slice	Interest	2.1a Yes	2.1a No	2.1b Yes	2.1b No	2.2a Yes	2.2a No	2.2b Yes	2.2b No	2.3a Yes	2.3a No
0	Control Lebanon	100	-100	100	-100	100	-100	100	-100	100	-100
	Defend Lebanon	100	-100	100	-100	100	-100	100	-100	100	-100
	Resist Israel	100	-100	100	-100	100	-100	100	-100	50	-50
	Militia Capability	100	-100	100	-100	50	-50	150	-150	100	-100
	Protect/Svc Shi'a	50	-50	150	-150	100	-100	100	-100	100	-100
1	Control Lebanon	100	-100	100	-100	100	-100	100	-100	100	-100
	Defend Lebanon	100	-100	100	-100	100	-100	100	-100	100	-100
	Resist Israel	100	-100	100	-100	100	-100	100	-100	50	-50
	Militia Capability	100	-100	100	-100	50	-50	150	-150	100	-100
	Protect/Svc Shi'a	50	-50	150	-150	100	-100	100	-100	100	-100
2	Control Lebanon	100	-100	100	-100	100	-100	100	-100	100	-100
	Defend Lebanon	100	-100	100	-100	100	-100	100	-100	100	-100
	Resist Israel	100	-100	100	-100	100	-100	100	-100	50	-50
	Militia Capability	100	-100	100	-100	50	-50	150	-150	100	-100
	Protect/Svc Shi'a	50	-50	150	-150	100	-100	100	-100	100	-100

Slice	Interest	2.3b Yes	2.3b No	2.4a Yes	2.4a No	2.4b Yes	2.4b No	2.5a Yes	2.5a No	2.5b Yes	2.5b No
0	Control Lebanon	100	-100	100	-100	100	-100	50	-50	150	-150
	Defend Lebanon	100	-100	50	-50	150	-150	100	-100	100	-100
	Resist Israel	150	-150	100	-100	100	-100	100	-100	100	-100
	Militia Capability	100	-100	100	-100	100	-100	100	-100	100	-100
	Protect/Svc Shi'a	100	-100	100	-100	100	-100	100	-100	100	-100
1	Control Lebanon	100	-100	100	-100	100	-100	50	-50	150	-150
	Defend Lebanon	100	-100	50	-50	150	-150	100	-100	100	-100
	Resist Israel	150	-150	100	-100	100	-100	100	-100	100	-100
	Militia Capability	100	-100	100	-100	100	-100	100	-100	100	-100
	Protect/Svc Shi'a	100	-100	100	-100	100	-100	100	-100	100	-100
2	Control Lebanon	100	-100	100	-100	100	-100	50	-50	150	-150
	Defend Lebanon	100	-100	50	-50	150	-150	100	-100	100	-100
	Resist Israel	150	-150	100	-100	100	-100	100	-100	100	-100
	Militia Capability	100	-100	100	-100	100	-100	100	-100	100	-100
	Protect/Svc Shi'a	100	-100	100	-100	100	-100	100	-100	100	-100

Table 13.   Variations on Scenario 2

GeNIe is used again to solve the network, with the same distributions as in Scenario 1. Table 14 contains the average reward for each scenario.

Scenario	2	2.1a	2.1b	2.2a	2.2b	2.3a	2.3b	2.4a	2.4b	2.5a	2.5b
Average	574	489	659	487	661	506	642	514	634	586	562
Max	1153	1017	1289	1017	1290	1033	1273	1039	1267	1083	1224
Min	-15	-59	29	-53	22	-36	6	-19	-11	99	-129

Table 14.   Scenario 2 results

The results from Scenario 2 show that Scenarios 2.2a and 2.2b, wherein the interest of "LH possessing a militia capability" was varied, resulted in the largest deviation from the base case in terms of expected reward.   Scenarios 2.5a and 2.5b, where the interest of "LH controlling Lebanon" varied, resulted in the smallest deviation from the base case.   The tornado diagram, for the results shown in Table 14, are shown in Figure 18.
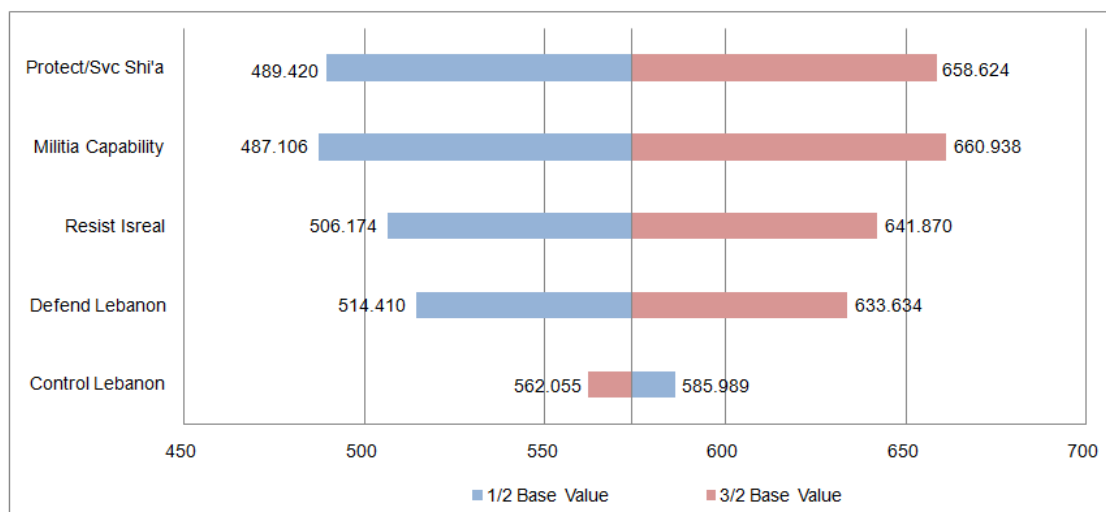

Figure 18.   Tornado diagram for Scenario 2

The interests most sensitive to variations from the base case are ordered slightly differently than the results in Scenario 1.   LH's interest in "possessing a militia capability" surpasses "LH protecting and providing services to the Shi'a in Lebanon."   The third and fourth most important interest to the model similarly switch order, where "LH resisting Israel" surpasses "LH defending Lebanon."   As in Scenario 1, "LH controlling Lebanon" is the least important interest.

3. Scenario 3

In the third set of scenarios, the values of interests, are returned to their SME values. The values of interests remain fixed in this third scenario and are not varied as before in Scenarios 1 and 2. Instead, distributions will be varied by reducing their value by half (a), then by increasing their value by adding half the difference to 1 (b). Tables 15–17 show the values for each of these scenarios.

Slice	Interest		3.0 Diasp Spt LH		3.0 Not	
			LB Spt LH	Not	LB Spt LH	Not
All	Control Lebanon	Control	0.80	0.30	0.70	0.00
		Not	0.20	0.70	0.30	1.00
	Defend Lebanon	Defend	1.00	0.70	0.90	0.50
		Not	0.00	0.30	0.10	0.50
	Resist Israel	Resist	0.95	0.80	0.60	0.50
		Not	0.05	0.20	0.40	0.50
	Militia Capability	Possess	1.00	0.90	0.70	0.50
		Not	0.00	0.10	0.30	0.50
	Protect/Svc Shi'a	Provide	1.00	0.70	0.80	0.60
		Not	0.00	0.30	0.20	0.40

Table 15. Scenario 3 (base case for Scenario 3)

Slice	Interest		3.1a Diasp Spt LH		3.1a Not		3.1b Diasp Spt LH		3.1b Not	
			LB Spt LH	Not	LB Spt LH	Not	LB Spt LH	Not	LB Spt LH	Not
All	Control Lebanon	Control	0.80	0.30	0.70	0.00	0.80	0.30	0.70	0.00
		Not	0.20	0.70	0.30	1.00	0.20	0.70	0.30	1.00
	Defend Lebanon	Defend	1.00	0.70	0.90	0.50	1.00	0.70	0.90	0.50
		Not	0.00	0.30	0.10	0.50	0.00	0.30	0.10	0.50
	Resist Israel	Resist	0.95	0.80	0.60	0.50	0.95	0.80	0.60	0.50
		Not	0.05	0.20	0.40	0.50	0.05	0.20	0.40	0.50
	Militia Capability	Possess	1.00	0.90	0.70	0.50	1.00	0.90	0.70	0.50
		Not	0.00	0.10	0.30	0.50	0.00	0.10	0.30	0.50
	Protect/Svc Shi'a	Provide	0.50	0.35	0.40	0.30	1.00	0.85	0.90	0.80
		Not	0.50	0.65	0.60	0.70	0.00	0.15	0.10	0.20

Slice	Interest		3.2a Diasp Spt LH		3.2a Not		3.2b Diasp Spt LH		3.2b Not	
			LB Spt LH	Not	LB Spt LH	Not	LB Spt LH	Not	LB Spt LH	Not
All	Control Lebanon	Control	0.80	0.30	0.70	0.00	0.80	0.30	0.70	0.00
		Not	0.20	0.70	0.30	1.00	0.20	0.70	0.30	1.00
	Defend Lebanon	Defend	1.00	0.70	0.90	0.50	1.00	0.70	0.90	0.50
		Not	0.00	0.30	0.10	0.50	0.00	0.30	0.10	0.50
	Resist Israel	Resist	0.95	0.80	0.60	0.50	0.95	0.80	0.60	0.50
		Not	0.05	0.20	0.40	0.50	0.05	0.20	0.40	0.50
	Militia Capability	Possess	0.50	0.45	0.35	0.25	1.00	0.95	0.85	0.75
		Not	0.50	0.55	0.65	0.75	0.00	0.05	0.15	0.25
	Protect/Svc Shi'a	Provide	1.00	0.70	0.80	0.60	1.00	0.70	0.80	0.60
		Not	0.00	0.30	0.20	0.40	0.00	0.30	0.20	0.40

3.3a / 3.3b

Slice	Interest		3.3a Diasp Spt LH LB Spt LH	3.3a Diasp Spt LH Not	3.3a Not LB Spt LH	3.3a Not Not	3.3b Diasp Spt LH LB Spt LH	3.3b Diasp Spt LH Not	3.3b Not LB Spt LH	3.3b Not Not
All	Control Lebanon	Control	0.80	0.30	0.70	0.00	0.80	0.30	0.70	0.00
		Not	0.20	0.70	0.30	1.00	0.20	0.70	0.30	1.00
	Defend Lebanon	Defend	1.00	0.70	0.90	0.50	1.00	0.70	0.90	0.50
		Not	0.00	0.30	0.10	0.50	0.00	0.30	0.10	0.50
	Resist Israel	Resist	0.48	0.40	0.30	0.25	0.98	0.90	0.80	0.75
		Not	0.53	0.60	0.70	0.75	0.03	0.10	0.20	0.25
	Militia Capability	Possess	1.00	0.90	0.70	0.50	1.00	0.90	0.70	0.50
		Not	0.00	0.10	0.30	0.50	0.00	0.10	0.30	0.50
	Protect/Svc Shi'a	Provide	1.00	0.70	0.80	0.60	1.00	0.70	0.80	0.60
		Not	0.00	0.30	0.20	0.40	0.00	0.30	0.20	0.40

3.4a / 3.4b

Slice	Interest		3.4a Diasp Spt LH LB Spt LH	3.4a Diasp Spt LH Not	3.4a Not LB Spt LH	3.4a Not Not	3.4b Diasp Spt LH LB Spt LH	3.4b Diasp Spt LH Not	3.4b Not LB Spt LH	3.4b Not Not
All	Control Lebanon	Control	0.80	0.30	0.70	0.00	0.80	0.30	0.70	0.00
		Not	0.20	0.70	0.30	1.00	0.20	0.70	0.30	1.00
	Defend Lebanon	Defend	0.50	0.35	0.45	0.25	1.00	0.85	0.95	0.75
		Not	0.50	0.65	0.55	0.75	0.00	0.15	0.05	0.25
	Resist Israel	Resist	0.95	0.80	0.60	0.50	0.95	0.80	0.60	0.50
		Not	0.05	0.20	0.40	0.50	0.05	0.20	0.40	0.50
	Militia Capability	Possess	1.00	0.90	0.70	0.50	1.00	0.90	0.70	0.50
		Not	0.00	0.10	0.30	0.50	0.00	0.10	0.30	0.50
	Protect/Svc Shi'a	Provide	1.00	0.70	0.80	0.60	1.00	0.70	0.80	0.60
		Not	0.00	0.30	0.20	0.40	0.00	0.30	0.20	0.40

3.5a / 3.5b

Slice	Interest		3.5a Diasp Spt LH LB Spt LH	3.5a Diasp Spt LH Not	3.5a Not LB Spt LH	3.5a Not Not	3.5b Diasp Spt LH LB Spt LH	3.5b Diasp Spt LH Not	3.5b Not LB Spt LH	3.5b Not Not
All	Control Lebanon	Control	0.40	0.15	0.35	0.00	0.90	0.65	0.85	0.50
		Not	0.60	0.85	0.65	1.00	0.10	0.35	0.15	0.50
	Defend Lebanon	Defend	1.00	0.70	0.90	0.50	1.00	0.70	0.90	0.50
		Not	0.00	0.30	0.10	0.50	0.00	0.30	0.10	0.50
	Resist Israel	Resist	0.95	0.80	0.60	0.50	0.95	0.80	0.60	0.50
		Not	0.05	0.20	0.40	0.50	0.05	0.20	0.40	0.50
	Militia Capability	Possess	1.00	0.90	0.70	0.50	1.00	0.90	0.70	0.50
		Not	0.00	0.10	0.30	0.50	0.00	0.10	0.30	0.50
	Protect/Svc Shi'a	Provide	1.00	0.70	0.80	0.60	1.00	0.70	0.80	0.60
		Not	0.00	0.30	0.20	0.40	0.00	0.30	0.20	0.40

Table 16.   Variations on Scenario 3

GeNIe is used once again to solve the network, using Scenario 1 as the fixed values for interests, but varying the distributions of interests as shown in Table 16. Table 17 contains the average reward for each scenario.

Scenario	3	3.1a	3.1b	3.2a	3.2b	3.3a	3.3b	3.4a	3.4b	3.5a	3.5b
Average	401	127	478	273	433	313	434	315	426	358	454
Max	721	383	735	570	733	613	735	606	722	641	744
Min	78	-145	205	-26	134	8	128	23	134	77	171

Table 17.   Scenario 3 results

Scenarios 3.1a and 3.1b, where the interest of "LH protecting and providing services to the Shi'a in Lebanon" are varied, result in the largest deviation from the base case. The tornado diagram for the results shown in Table 17 is similar as that shown in Figure 19.
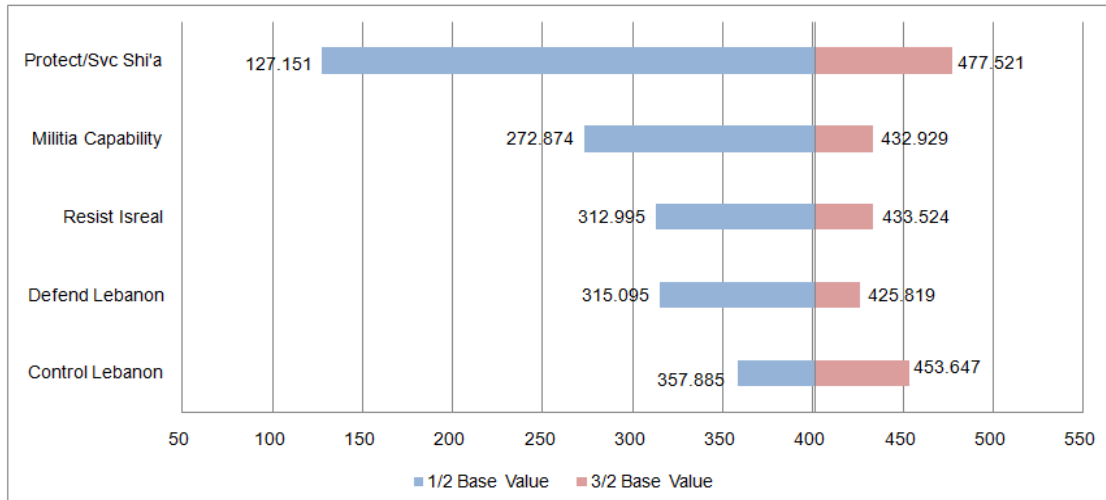
Figure 19.   Tornado diagram for Scenarios 3

Figure 19 clearly shows that the distributions associated with "LH protecting and providing services to the Shi'a in Lebanon" are clearly the most important factor of the model.

4.   2-Slice Model

How might LH's optimal strategy change if the model were reduced to 2 slices? This is akin to assuming LH might not be consumed with how the state space will evolve in three years, but rather just two—a slightly shorter-term perspective. The ID is easily pruned in GeNIe, as shown in Figure 20.
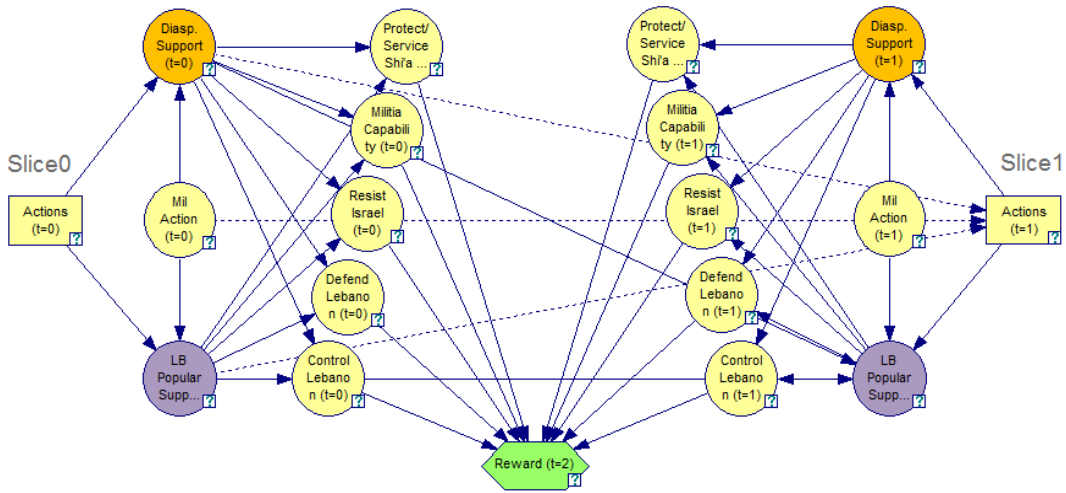
Figure 20.   GeNIe implementation of 2-slice model

We use the base case Scenarios 1 and 2 for this iteration of GeNIe solution to the model.

Table 18.   2-slice model optimizing action at t=0

Table 19.   2-slice model optimizing action at t=1

Table 20.   2-slice model reward node

The optimal strategy, as calculated by GeNIe, for the 2-slice model suggests that in the first slice, LH would maximize its expected reward by "increasing illicit activities."   In the second slice, no matter how the state space transitioned after the first slice, LH would invariably maximize its expected reward by "increasing outreach to the Lebanese Diaspora."   Its optimal strategy, given by the reward node, is to "increase outreach to the Lebanese Diaspora" in t=1, regardless of the condition of the state space.   We thus have, for the 2-slice model, a similarly bleak forecast for improved relations for Israel and the West according to the following summary of LH's optimal strategy:

t=0: Increase illicit activities

t=1: Increase outreach to the Lebanese Diaspora

5.   1-Slice Model

We repeat the process from the previous section, this time studying how the optimal strategy changes if the model were reduced to just 1-slice. Such a model assumes that LH is only concerned with its immediate rewards, where it will be and how the state space will transition within 1 year. We prune the ID again, as shown in Figure 21.
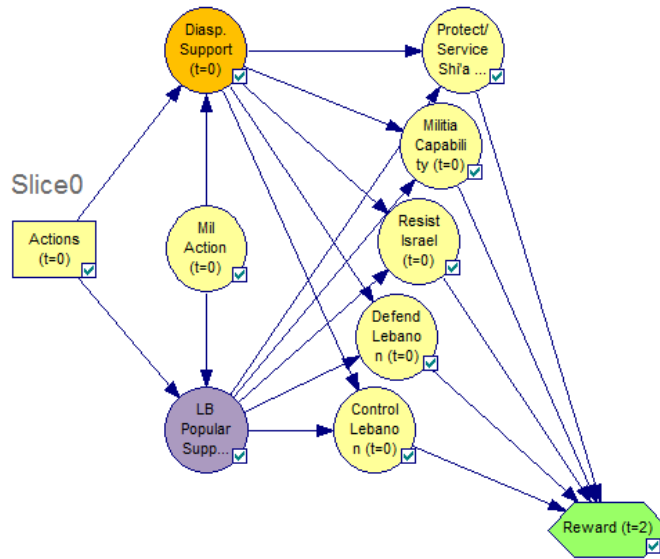

Figure 21.   GeNIe implementation of 1-slice model

We again use the base case Scenarios 1 and 2 for this iteration of GeNIe's solution to the model.

Table 21.   1-slice model optimizing action at t=0

Table 22.   1-slice model reward node

LH's optimal strategy for the 1-slice model is to "expand goods and services beyond the Shi'a in Lebanon." This model's results is the most favorable in terms of the state space transitioning towards conditions that would facilitate improved relations with Israel and the West–provided LH would ever prove to be so short-sighted, and interested only in the rewards of the very near-term.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

This study provides a dynamic model for answering the UCC's LH question. The methodology and tools (DMAPS and GeNIe) employed to this end can be applied for the analysis of other stakeholders and their decision-making process.

As in this and all models, the reliability of forecasted optimal strategies are directly related to the quality of the SME data input as the values and distributions that ultimately determine the behavior of the model.

B. RECOMMENDATIONS

1. For Defense and Diplomacy Consideration

It is clear, from the results and sensitivity analysis studied in Chapter IV, sections A.1 and B.1-2, that the United States, Israel and the West ought to invest in understanding how they might be able to fulfill LH's interest of "protecting and providing services to the Shi'a in Lebanon." Also, being able to affect LH's propensity to "develop a closer relationship with Iran" and for LH to "increase its outreach to the Lebanese Diaspora" may affect the actions LH decides to take in effort to maximize its reward. Such understanding, further modeling, and eventual application of force, diplomacy or economic persuasions may in fact enable the West to mold the state space and the actions LH takes to achieve more favorable and peaceful conditions in the Middle East.

2. Future Work

Due to time constraints and the capacity of the operating memory of computer software, this study provided a dynamic model and analysis for one of two key questions the UCC has regarding LH. The second question, *"How will*

Syria's potential/likely decisions and actions affect their relationship with LH?" adds a dimension to the methodology used in thesis' LH question: the two player-game. While the same principles of game theory and decision analysis were applied, in this thesis can be applied to a two-stakeholder dynamic model. The dimensionality involved and the software computing requirements, will require further study and development.

LIST OF REFERENCES

Abbas, A. 2004. *Entropy Methods for Adaptive Utility Elicitation*. IEEE Transactions on Systems, Man and Cybernetics. No. 34.

Allison, Graham T. 1999. *Essence of Decision: Explaining the Cuban missile crisis*. New York: Addison-Wesley Publishers.

Bueno de Mesquita, B. 2009. *The Predictioneer's Game: Using the logic of brazen self-interest to see and shape the future*. 1st ed. New York: Random House.

——. 2003. *The Logic of Political Survival*. Cambridge, Mass.: MIT Press.

Bueno de Mesquita, B, Newman, D., and Rabushka, A. 1985. *Forecasting Political Events: The future of Hong Kong*. New Haven: Yale University Press.

Friedman, T. 2002. *Longitudes and Attitudes: Exploring the world after September 11*. 1st ed. New York: Farrar, Strauss and Giroux.

——. 1990. *From Beirut to Jerusalem*. New York: Farrar, Straus, Giroux.

Howard, R. and Matheson, J. 2005. *Influence Diagrams*. INFORMS – Decision Analysis. No. 2.

Mitroff, I. and Silvers, A. 2010. *Dirty Rotten Strategies: How we trick ourselves and others into solving the wrong problems precisely*. High reliability and crisis management. Stanford, CA: Stanford Business Books.

Nasr, V. 2007. *The Shia Revival: How conflicts within Islam will shape the future*. New York: W.W. Norton.

Norton, A. 2007. *Hezbollah: A short history*. Princeton studies in Muslim politics. Princeton: Princeton University Press.

Paté-Cornell, E. and Guikema, S. 2002. *A Systems Analysis Approach to Setting Priorities Among Countermeasures*. Military Operations Research. No. 7.

Qasim, N. 2005. *Hizbullah: The story from within* [Ḥizb Allāh.]. London: Saqi.

Straffin, P. 1993. *Game Theory and Strategy*. New mathematical library. No. 36. New York: The Mathematical Association of America.

Ziser, E. 2007. *Commanding Syria*. Library of Modern Middle East Studies. No. 60. London: Tauris.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1.   Defense Technical Information Center
        Ft. Belvoir, Virginia

2.   Dudley Knox Library
        Naval Postgraduate School
        Monterey, California

3.   Marine Corps Representative
        Naval Postgraduate School
        Monterey, California

4.   Director, Training and Education, MCCDC, Code C46
        Quantico, Virginia

5.   Director, Marine Corps Research Center, MCCDC, Code C40RC
        Quantico, Virginia

6.   Marine Corps Tactical Systems Support Activity (Attn: Operations Officer)
        Camp Pendleton, California

7.   LTC Lee Ewing
        Operations Research Department, Naval Postgraduate School
        Monterey, California

8.   CAPT Jeff Kline
        Operations Research Department, Naval Postgraduate School
        Monterey, California

9.   CAPT Barbara Ford
        Business School, Naval Postgraduate School
        Monterey, California